SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

1949 Literature Review—Research Committee

Distillery Waste Treatment—Davidson

Stream Data Evaluation—Velz

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MAY, 1950—VOL. 22, No. 5

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TWENTY-THIRD ANNUAL MEETING

OF THE

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IN CONJUNCTION WITH

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AND

FEDERAL SEWAGE RESEARCH ASSOCIATION

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October 9-12, 1950

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325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

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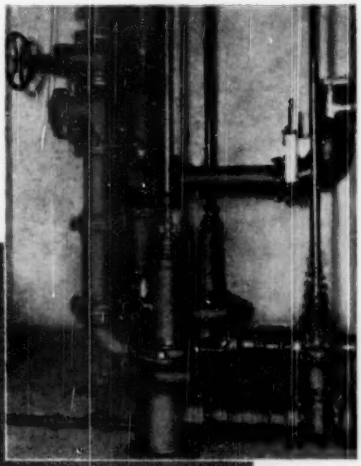

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"Flush-Kleens" are absolutely clog-proof . . . the impellers handle nothing but strained sewage, minimizing wear and maintaining pump balance. They need no manual attention other than lubrication and inspection. No labor is needed to dis-assemble and clean. Not just another practically non-clog pump—"Flush-Kleens" are *positively* clog-proof.

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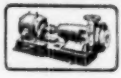

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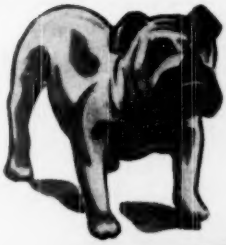

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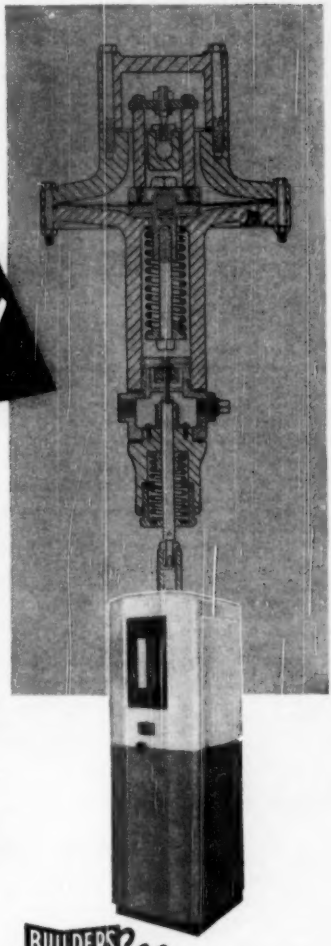

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Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-5.

Centrifugal, axial and mixed flow pumps for all applications.

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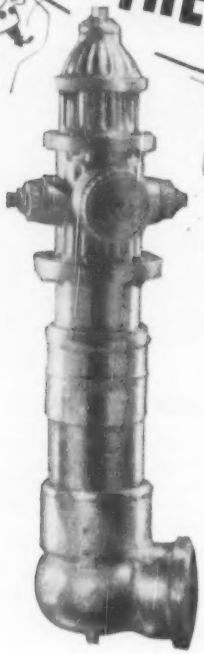
DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO



WE ARE LOOKING FORWARD to seeing you at the A.W.W.A. Convention to be held in Philadelphia from May 21 to 26. A most friendly welcome awaits you, and we hope that many of you will take the opportunity to get better acquainted with our products by visiting our plant in Florence, N. J., near Philadelphia.

At the Convention, our products will be on display in Booths 217 and 219. Come and see for yourself how simplicity of design and ease of replacement make the Modernized Mathews Hydrant a vital link in the fire fighting system of every modern, safety-minded community.

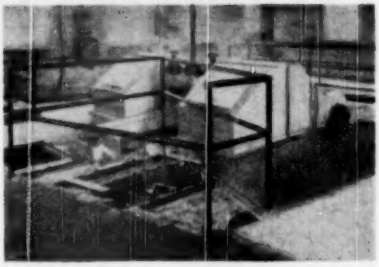
MATHEWS HYDRANTS

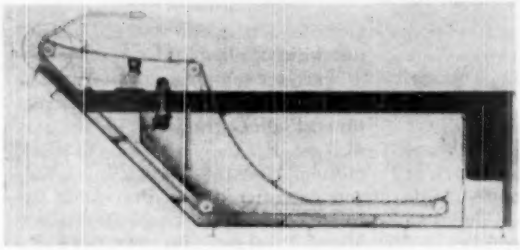
Made by R. D. WOOD COMPANY
Public Ledger Bldg., Independence Square, Phila. 5, Pa.
Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Let Link-Belt Help You Dispose of *Industrial Wastes*

Safeguard public health or salvage valuable by-products from waste water, or perhaps do both, by means of Link-Belt equipment for water, sewage and industrial waste treatment. Note the four typical applications here shown.

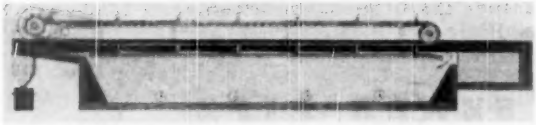
Link-Belt engineers, with a broad line of equipment and extensive experience, can aid you in planning and installing the right type of plant to solve your specific waste problems.



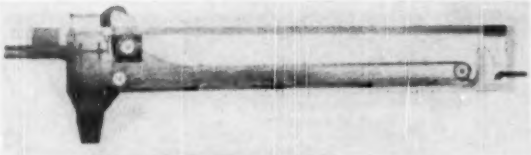


Above: Waste recovery system at large glue factory, consisting of enclosed revolving screens with settling pit and dewatering screw conveyor for the screenings.

Left: Coolant clarifying system utilizing Link-Belt dewatering conveyor. After clarification, coolant may be filtered or returned direct to grinding machines.



Left: Paper stock is recovered in the Link-Belt Save-All by a mechanical skimmer which collects the floating stock with a minimum of water.



Left: Heavy grit and detritus is removed from flume water at sugar beet factories, by settling in a tank equipped with a Link-Belt grit collector.

The Link-Belt line includes screens, sludge collectors, grit collectors, grit washers, chemical mixers, sludge dryers, power transmitting, elevating and conveying machinery.

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Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

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Sanitary Engineering Equipment

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Write for complete data and ask too about these other Armco sewer structures: Plain Galvanized Pipe for normal use, PAVED-INVERT Pipe to check erosion, ASBESTOS-BONDED Pipe for severe corrosive service, PIPE-ARCH for limited headroom. Armco Drainage & Metal Products, Inc., 4470 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

ARMCO

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ACCELO® FILTER

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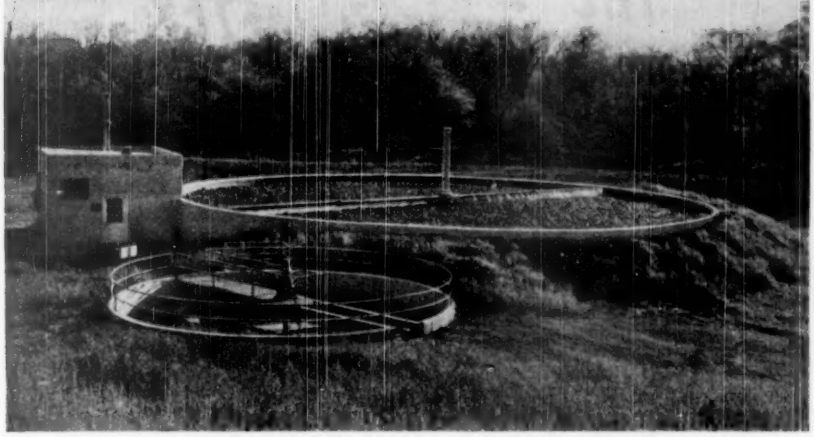

ACCELO FILTER INSTALLATION AT WHITEHALL, ILLINOIS

Direct Recirculation can be easily Included in any Treatment Plant!

Biological oxidation is greatly accelerated by the Accelo Filter in the treatment of sewage and other organic wastes. This is accomplished by recirculating large quantities of the fresh unsettled trickling filter effluent directly back to the inlet of the filter distribution equipment. This method of operation eliminates many of the nuisances common to the conventional trickling filter. The ACCELO FILTER System may be used to give increased capacity to overloaded conventional trickling filters as it makes higher dosing rates possible. Other advantages include: 1. Increased biological filter efficiency, 2. No increase in size of sedimentation tanks, 3. Smaller trickling filters, 4. No clogging, sloughing or ponding, 5. No odors, 6. Reduction of psychoda fly nuisance.

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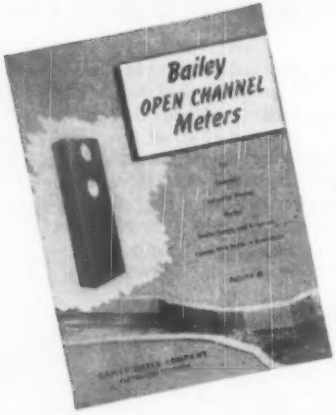

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INDUSTRIAL WASTES

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IRRIGATION WATER

Ask For Bulletin 62

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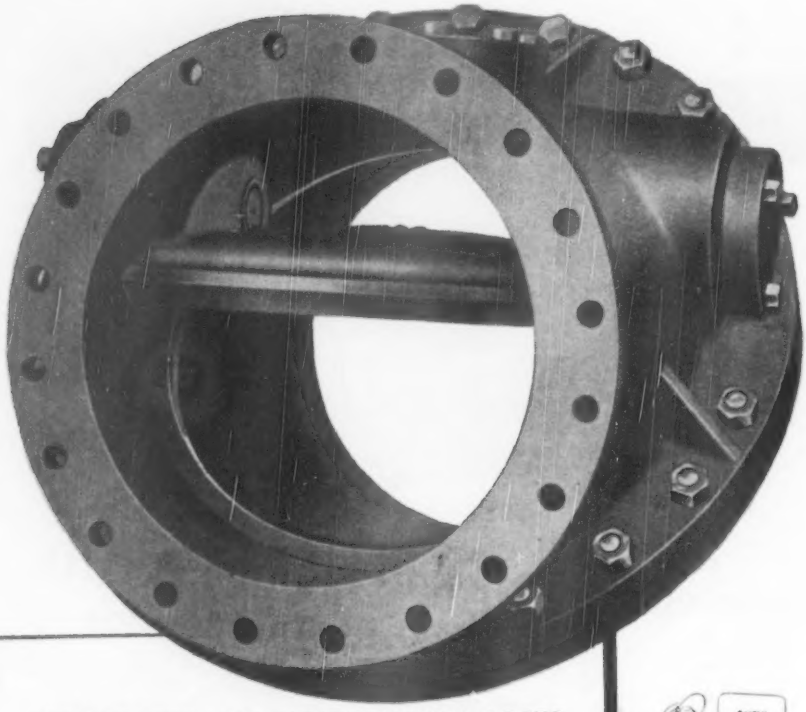

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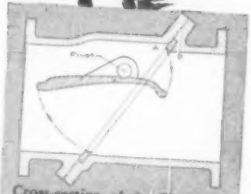

Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

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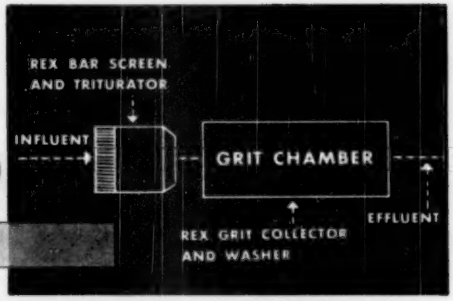
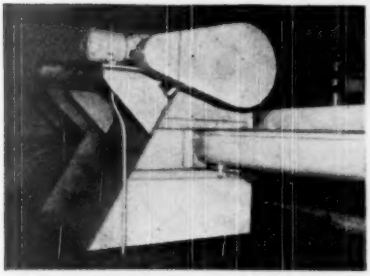


LINE-UP for EFFECTIVE SEPARATION

For most effective separation and removal of inorganic solids from liquids, rely on Rex Mechanically Cleaned Bar Screens and Rex Grit Collectors. At the Boat Harbor Sewage Treatment Plant in Newport News, for example, these efficient units are more than meeting the requirements. Two Rex type "MA" Bar Screens in channels 3′ wide x 15′ 6″ deep effectively remove large solids. The Rex Features . . . large bar rack area exposed to flow; straight, unobstructed flow; low head loss; large reserve capacity; rugged design; low installation and operating costs . . . assure maximum efficiency.



Rex V-Bucket Type Grit Collectors employing the Rex Recirculation Process for effective grit control at Boat Harbor Plant.

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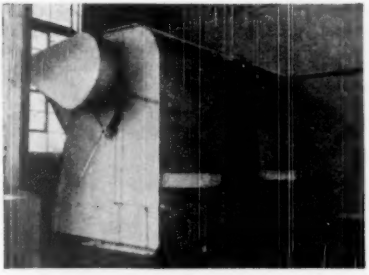

Rex Type MA Mechanically Cleaned Bar Screens equipped with Rex Triturators at Boat Harbor Plant.

Two Rex V-Bucket Type Grit Collectors effectively separate and remove inorganic grit from the flow. Buckets carry and elevate the grit to a hopper which in turn feeds the grit into a cross screw conveyor. Conveyor discharges the grit into buckets for disposal. An important advantage of Rex Grit Collectors is their built-in recirculation process which provides effective control of grit quality. All grit is returned to the top of the incoming average or normal flow at the channel entrance. Organic material is thus carried out of the channel for further treatment . . . only concentrated grit resettles for disposal.

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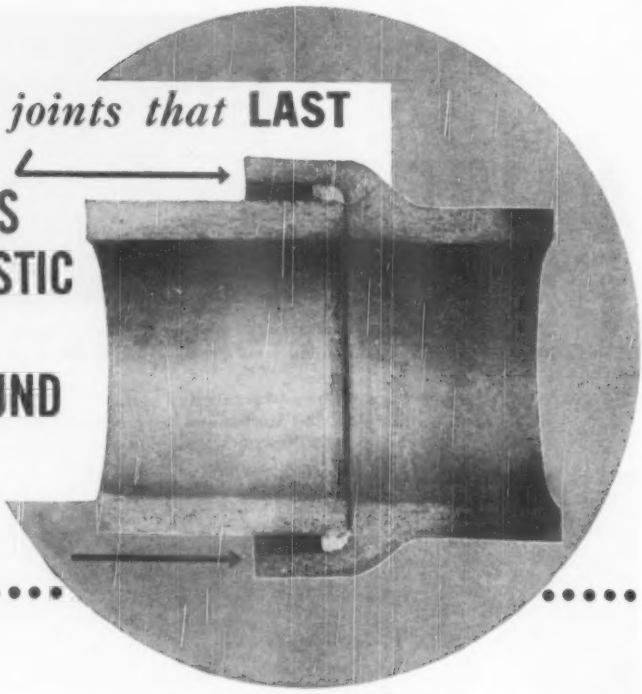

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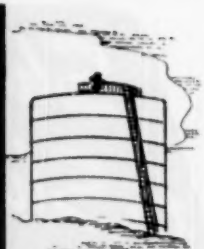

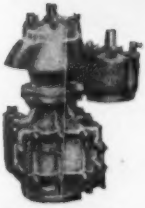

Fig. No. 5800C

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LABORATORY GAS LINE PROTECTION – "VAREC" Figure No. 52A Flame Check

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Fig. No. 187

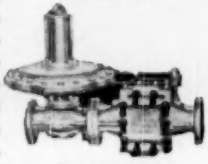

Fig. No. 440

Fig. No. 280A

Fig. No. 52A

Fig. No. 450

Fig. No. 70

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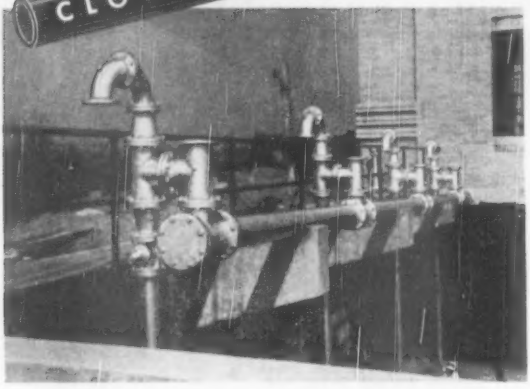

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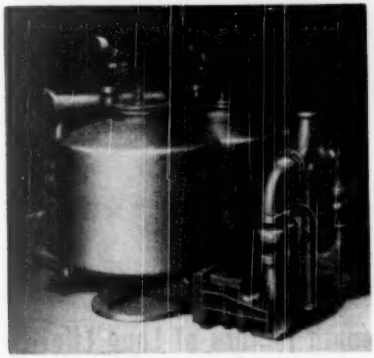

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SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 | MAY, 1950 | Number 5

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

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Washington, Blue Plains Plt.	2	1944-45	136.3	12	160' Dia.	14	1.86	1350	163	83	49	6.85	67.5	173	120	30.5
Gary, Ind.	4	1941-44	20.11	4	75' Sq.	10	2.8	980	285	104	61	5.32	63	140	72	47.2
Winnipeg, Man.	2	1943-44	22.8	2	115' Dia.	12	1.98	1180	348	150	56	8.0	70.5	310	231	25.5
Battle Creek, Mich.	5	1938-42	4.92	2	80' Dia.	10	3.88	490	262	85	70	5.5	62.5	284	174	34.1
Buffalo, N. Y.	3	1939-41	135	4	160' "	15	1.6	1080	298	114	48	5.77	59	138	107	22.5
Albuquerque, N. M.	7	1939-48	5	1	80' "	12.2	2.21	985	254	91	61	3.98	61	282	158	44.5
Yakima, Wash.	1	1942	9.5	4	90' "	9	4.32	373	116	23	74	6.98	74.4	175	92	58
Appleton, Wis.	7	1938-45	4.8	2	70' "	10	2.99	823	276	63	77	5.6	59	284	141	50
Baltimore, Md.	4	1939-44	80.5	3	170' "	12	1.84	1360	214	83	61	3.9	82.7	281	204	27.5
Springfield, Ohio	4	1937-40	14.8	2	80' "	10	1.55	1160	186	83	62	—	—	80	43	57
Mansfield, Ohio	2	1944-45	3	1	85' "	12	2.38	985	288	87	58	4.2	78	227	139	38.8
Cedar Rapids, Ia.	9	1938-44	4.21	1	70' "	11.5	1.95	1080	354	132	63	5.5	81.2	303	291	24
Austin, Texas	2	1944-45	5.84	1	75' "	12	1.89	1275	283	86	84	4.1	83	295	152	48.3
Neenah-Menasha, Wis.	4	1942-45	7.83	2	70' "	10	1.8	1700	691	188	72	--	—	—	—	—
Denver, Colo.	5	1939-43	46	4	140' "	9.7	2.34	750	187	44	77	5.4	78	212	108	49
Sheboygan, Wis.	1	1944	9.4	2	80' "	10	2.8	635	342	89	82	7.2	81.1	513	285	44
Ypsilanti, Mich.	3	1943-45	1.88	2	40' "	9	2.5	960	226	87	62	8.2	71.4	141	95	33
Monroe, Mich.	8	1938-48	4.3	2	85' "	7.5	3.55	370	329	75	77	5.23	67.7	135	73	46

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Sewage Works

A CRITICAL REVIEW OF THE LITERATURE OF 1949 ON SEWAGE AND WASTE TREATMENT AND WATER POLLUTION

By W. Rudolfs, *Chairman*, H. E. Babbitt, D. E. Bloodgood, G. P. Edwards, H. A. Faber, W. H. Gehm, A. L. Genter, H. Heukelekian, R. D. Hoak, M. Kratz, H. J. Miles, F. W. Mohlman, W. A. Moore, H. Orford, C. C. Ruchhoft, N. H. Sanborn, C. N. Sawyer, L. R. Setter, J. Tsivoglou, L. W. Van Kleeck, and J. S. Wiley

Committee on Research, Section A, Federation of Sewage Works Associations

The literature on sewage, industrial waste, and stream pollution has been expanding rapidly. The first annual review for 1932–33 listed 122 papers for the two-year period. After 10 years the number of papers reviewed had increased to 232 a year. For several war years the number of papers remained about constant, increased to 287 in 1948, and with this 18th annual review increased to 398 references. The recent increases are almost entirely the result of greater interest in industrial wastes and stream pollution.

The fear that the poliomyelitis virus may be transmitted through domestic sewage has been relegated to a theoretical possibility. No convincing evidence has been presented that pollution of water supplies or polluted bathing places was responsible for infection with the virus. The danger of using sewage and sewage sludge for agricultural purposes seems to have been overrated.

Many investigators have played with the idea of using oxygen instead of air for the oxidation of organic matter. Laboratory results now have been produced to show that a concentrated biological floc may be maintained with pure oxygen, resulting in an increased rate of oxidation. Application of the principle is now awaited to determine its economic feasibility.

The tremendous increase in the use of detergents since the last war has created considerable apprehension among sewage plant operators. Increases in load on secondary treatment devices, decrease in gas production, and possible effect on dewatering of sludge, together with finding 4 to 6 ft. of foam on aerators in activated sludge plants, does not allay the fears despite reassuring statements made by certain manufacturers. Chances are that a considerable amount of information will become available during the next few years.

Another waste which causes uneasiness is that from radioactive materials. To date most of the papers published do not give much information regarding the real or imagined dangers. The absence of pertinent information regarding the treatment of liquid radioactive wastes is probably caused by the fact that studies on the effects of the wastes on biological communities are in their infancy. It appears, however, that within the limits of national security, information will be forthcoming as rapidly as it is available.

In the industrial waste treatment field, materials which may be consid-

ered toxic or having a preserving action appear to be capable of being treated by biological devices. In addition to the well-known phenol treatment method, we have now the adaptation of biological filters to formaldehyde. It appears that a specific flora and fauna can be developed readily to take care of such types of wastes.

The treatment of organic waste, such as yeast and antibiotics, seems to follow the general biological methods employed for sewage. Of interest is the rediscovery of effective digestion of strawboard waste, which was practiced on a large scale at least as early as 1914. It seems that many practices are rediscovered at least once every generation.

Worthy of note is the interest in the use of chlorine for treatment of industrial wastes. The information regarding the effect of chlorine on oxygen consumed, B.O.D., color, and toxicity of industrial waste is very meager or non-existent. The possibilities of using this chemical tool warrant considerable study.

General

Disease

Interest in the spread of disease by sewage and sludge continues. Gear and Measrock (134) found poliomyelitis virus in raw sludge and in primary and humus tank effluents. The presence of the virus could not be detected in digested sludge, sand filter effluent, and in psychoda flies. The virus was still present in the sewage two months after the last known poliomyelitis case had occurred in the area in Johannesburg, South Africa. The virus was detected regularly when the epidemic had reached its peak. On three occasions when the settled sewage was positive, the sand filter effluent was negative. Vegetables grown on land irrigated with humus tank effluent did not show the presence of the virus.

Maxcy (246) concluded that the occasional finding of the poliomyelitis virus in domestic sewage during a period of high prevalence is without significance in the transmission of the disease unless or until it can be shown through what channels the virus may reach the alimentary tract of human beings. It has not been traced beyond the effluent from sewage plants. That it may occasionally survive the conditions which effect natural purification in rivers and lakes and reach the intake of a water system, he considers only a theoretical possibility. Despite the extensive investigations there is no instance on record in which convincing evidence has been presented that pollution of water supply was responsible for infection with the virus. Brown (74) emphasized that with the exception of infectious hepatitis, milk and water, if involved, do not represent the major vehicle of infection of any of the virus diseases. The route of transmission of poliomyelitis seems to be personal association with either oropharyngeal or the gastro-intestinal discharges of infected individuals. Fecal contamination of milk and water, though potential vectors, accounts for only occasional infection.

A discussion of the role of the sludge digestion process to the problem of disease was given by McLachlan (249) in a symposium on the utilization of sewage sludges at the South African Branch of the Institute of Sewage Purification. The author recommended the adoption of a 3- to 6-month period as an ultimate safe detention for sludge digestion, including air drying and storage, for eliminating the risks of transmission by intestinal parasites, the *Salmonella* group of bacteria, and poliomyelitis virus. In the same symposium Wilson (387) discussed the risks of transmission of disease through the use of sewage sludges as fertilizer and the methods of rendering them safe.

Experimental work for the evaluation of the effect of various sewage treatment processes upon eggs of

Taenia saginata (beef tapeworm of man) was reported by Newton, Bennett, and Figgat (275). The results indicated that sedimentation of sewage would remove the majority of the eggs, but a considerable number would escape in the effluent. Sand filtration at the rate of 1 m.g.a.d. was very effective in removing the eggs. Digestion was found to be very slow in destroying the eggs. Trickling filters did not provide adequate protection. The activated sludge process has little effect on the eggs.

Falk (120) conducted field experiments to study the problem of contamination of tomatoes grown in polluted soils. Tomatoes were grown on sewage irrigated and nonirrigated plots. In another experiment the growing tomatoes were sprayed with a suspension of feces and *Esch. coli*. It was found that the coliform content of uncracked tomatoes grown on polluted soils was no greater than those from unpolluted soils. It made little difference whether the plots were irrigated during the growths of the plants or prior to planting. Tomatoes with cracked stem ends had a higher coliform content regardless of the pollution of the soil. When tomatoes were sprayed with feces or *Esch. coli* it was found that within a month the contamination had been reduced to or below the unsprayed controls. A species of *Salmonella* sprayed on tomatoes in the field could not be recovered after 7 days.

Biology

Recent investigations in the microbiology of sewage and industrial waste treatment processes are reviewed by Smit (330). The biology of sewage treatment processes is also discussed by Lackey (227). Barker (51), discussing the types of protozoa found in sewage, trickling filters, and activated sludge, emphasizes the seasonal fluctuation and the effect of sloughing on the protozoan populations of trickling filters. According to the author the function of protozoa is clarification, indirect stimulation of bacterial growth, direct destruction of soluble and insoluble matter, and mechanical agitation.

A study of the nature of sewer slimes, a laboratory method for investigation of such growths, their effect on sulfide production, and methods of controlling their growth, were presented by Beardsley (55). These growths have a high resistance to disinfectants. The effect of various metals, chlorine, organic disinfectants, such as chloro and bromo derivatives of benzene, aniline, phenol, chloroform, carbon tetrachloride, and quarternary ammonium compounds on the slimes and their sulfide producing activity were studied. Prevention of growths is more effective than destruction of existing growths.

A study of the biology of phenol-splitting microorganisms is presented by Lieb (236), including metabolism, strains, and culture media for phenol-splitting organisms. Strains isolated at 46° C. could not decompose phenol at 22° C.

Analytical Methods

The effect of temperature (5° to 20° C.) and sea water (0 to 18,300 p.p.m. chlorides) on the B.O.D. of sewage in bicarbonate dilution water was reported by Gotaas (144). The results showed that the rate of biological oxidation varies considerably under similar conditions. The data indicate that the rates are higher for low concentrations (550 to 6,000 p.p.m. chlorides) of sea water than in fresh water. For higher concentrations of sea water (greater than 9,000 p.p.m. Cl) the rates are progressively less than in fresh water. Sea water does not significantly affect the magnitude of the first-stage B.O.D. of sewage, but retards the second-stage B.O.D.

Comparative studies of dilution waters on the B.O.D. test were reported by Mick (255). There was little choice

between bicarbonate dilution water and mineralized phosphate water, with or without supplemental nitrogen, for determining the B.O.D. of raw or settled sewage. However, similar to other studies, the 5- and 10-day B.O.D. values were found to be excessively high when river samples were diluted with water fortified with ammonia salts, as compared to good agreement between bicarbonate and Formula C dilution water B.O.D. values.

From determinations of a 3-day B.O.D. and a 6-day B.O.D., Rhame (301) calculated k and L values on various raw, screened, and settled sewages. The L values approximated the dichromate oxygen consumed test developed by the author. The k values varied from 0.071 to 0.413 by the simplified determination, which may be subject to major error in the estimation of the L or ultimate B.O.D.

Rogers (304) recommends the calculation of the B.O.D. results of the various concentrations by conversion to 50 per cent oxygen depletion factor. A reseeding technique as a means of detecting toxic interference in the B.O.D. test of papermill effluents is suggested by Borden and Woodcock (69).

A discussion of routine estimation of B.O.D. is given by Lewin (234).

The methylene blue relative stability test was placed under automatic continuous observation by Ingols (191). Aerated sewage samples dosed with nitrate and methylene blue were placed in a photometer light path. Four photometer sets were connected to a single recording potentiometer, and the reduction of methylene blue to the colorless salt was measured at 2-min. intervals for each sample. The results obtained were considered unsatisfactory.

Abbott (3) reports that the addition of 1.5 to 4.8 p.p.m. of methylene blue to the B.O.D. dilution water suppresses nitrification of NH_3 to nitrite and inhibits the reduction of nitrate to nitrite while permitting the oxidation of organic matter to proceed at a normal rate.

The effect of various environmental factors on the biochemical oxygen demand of activated sludge was reported by Dawson and Jenkins (99). The results were obtained on 1 to 5 ml. of activated sludge in Warburg or Bancroft respirometers. The apparatus was described and graphs showed consistent and reproducible data.

After subjecting more than 30 organic compounds to replicate dichromate oxygen consumed tests at two acid concentrations, Moore, *et al.* (263) proposed refluxing 50-ml. samples for 2 hr. in the presence of 25 ml. of N/4 dichromate and 75 ml. conc. H_2SO_4, and back titrating the cool residual oxidant with standard ferrous ammonium sulfate. Ortho phenanthroline ferrous complex was used as an inside indicator having a very sharp endpoint. Seven compounds of over 30 selected for study were only slightly oxidized by both the dichromate method and an iodic acid method. Except for glutamic acid, which was 86 per cent oxidized by the dichromate method as against 99.9 per cent by the iodic acid method, the dichromate method was more efficient and reproducible in oxidizing those compounds which are amenable to chemical oxidation. The limitations of the dichromate, permanganate, ceric sulfate, and iodic acid methods are discussed. Additional studies on the permanganate O.C. at 30° to 40° C. and at boiling, as compared to B.O.D., were reported by Beeckmans and Beaujean (56).

An exhaustive investigation of the nitrite test has been made by Rider and Mellon (303). The study showed that superior accuracy and reproducibility could be achieved by diazotizing with sulfanilic acid at a low pH and coupling the diazotized complex with alpha-naphthylamine hydrochloride at a higher pH than recommended by Standard Methods (337). Proper pH adjustment may be secured for each

step by altering the concentration of acid (HCl) in the two reagents and using sodium acetate buffer in the coupling step. The paper should be consulted for details on the preparation of the reagents, the procedure, and the accuracies which were achieved when using a Beeckman spectrophotometer.

Baillie (50) used a photometer and alpha-naphthylamine hydrochloride in HCl for the nitrite test according to Standard Methods (337). The hydrochloride solution was easier to prepare and had superior keeping qualities. Good reproducibility was reported when transmittance of standards were compared with a calibration curve. It is questionable, however, that the claimed accuracy of "1 per cent or less" was reliable over the range of 100 to 6 per cent transmission, or 0 to 0.46 p.p.m. nitrite nitrogen.

In photometric analysis the plotting of absorptancy against logarithm of concentration has important advantage in evaluating the accuracy (46). Normally the most reliable range falls between an absorptancy range of 40 to 80 per cent.

A modified Sprengel reaction for the determination of nitrate nitrogen was reported by Provedi (298). Ten ml. of water sample treated with sodium acid salicylate was evaporated on a steam bath. Concentrated H_2SO_4 was added. After warming for several minutes on a steam bath, distilled water and a caustic solution were added and the nitrate determined colorimetrically.

According to Setter, *et al.* (323), the suspended solids of raw and settled sewage and activated sludge effluents at a particular plant were estimated with an accuracy comparable to the Gooch method. 400- to 800-ml. samples were homogenized in a Waring blender prior to measuring the absorbtancy in a photometer. A 15-ml. curvette having a 20-mm. light path was filled with blended sample and placed 145 to 165 mm. distant from the photo-cell to magnify the scattering of light due to turbidity. Depending on the type of samples, a range of 20 to 100 p.p.m. suspended solids fell in the reliable photometer range for a 20-mm. light path.

A filter paper method for the determination of suspended solids is described by Fraschina (131).

A test for settleable solids was suggested by Ludwig (239) from a study of the average results of suspended solids in raw sewage. Ten sewages were settled under quiescent conditions in 200-ml. beakers, and the supernatant suspended solids were determined every 15 to 30 min. for 4 hr. The same sewages were also coagulated without chemicals for 15 min. and settled for 20 min. before testing the supernatant suspended solids. From an analysis of the settling curves it was deduced that the ultimate removal of suspended solids by plain subsidence corresponded to the removal achieved from mixing the raw sewage for 15 min. at a paddle speed of 72 r.p.m., followed by 20 min. of settling. This relationship suggested the use of the latter technique in determining the ultimate volume of settleable solids as a quick substitute for the 2-hr. Imhoff cone test.

The relatively inferior assay for volatile acids in sewage sludges by Standard Methods (337) was greatly improved by Heukelekian and Kaplovsky (169). The proposed assay consists of (a) clarifying the sludge adjusted to a pH of 3.5 with acid, adding ferric chloride and filter aid, and filtering; (b) concentrating the filtrate by adjusting the pH to 11, evaporating, and cooling; (c) adjusting the pH to 4.0, saturating the residual solution with $MgSO_4$ and steam distilling the volatile acids; and (d) titrating the distillate with standard NaOH to pH 8.2. Recoveries of 92 to 98 per cent of acetic, proprionic, and butyric acid additions to sludges were reported, as contrasted with inferior recoveries by

Standard and other modified procedures.

Kirschman and Pomeroy (208) define the "oil" content of oil-field waste waters as the nonsaponifiable hexane-soluble fraction, which is relatively nonvolatile at normal laboratory temperatures. Comparative tests by two modified techniques gave similar results. One technique consisted of extracting the oil from 2.5 l. of water with three 200-ml. portions of chloroform, distilling off the CCl_4, treating the extract with ether-alcohol and caustic, extracting the nonsaponifiable matter with hexane, evaporating the hexane, and weighing the residue. The alternate technique consisted of flocculating a 2.5-l. sample with 5 millimols of zinc acetate and sodium carbonate, filtering and air-drying the settled floc, washing the original bottle with hexane, extracting the "oil" from the floc in a Soxhlet with hexane, and, after evaporation of solvent, weighing the extract. Flocculation with ferric hydroxide appeared less suitable than aluminum hydroxide or zinc carbonate on waters containing appreciable sulfide. Zinc carbonate was preferred as the floc filtered more readily than $Al(OH)_3$.

A procedure for the grease content of sewage sludges having minor variations over conventional procedures was reported by Stephenson (340). The acidified sludge (pH 2) was mixed to a smooth paste with an equal weight of $MgSO_4 \cdot H_2O$. The mixture was dried, ground, and extracted for 5 hr. with petroleum ether. The extract was then dried and weighed.

A methylene blue method for determining hydrogen sulfide was reported by Fogo and Popowsky (128). Hydrogen sulfide was absorbed from a stream of gas in a suspension formed by adding sodium hydroxide to a solution of zinc acetate. The suspension then containing the sulfide as zinc sulfide was treated with an acid solution of p-aminodimethylaniline, followed by the addition of a small amount of ferric chloride solution. After time had been allowed for the formation of the methylene blue, the solution was diluted in a volumetric flask and an aliquot was transferred to a photometer for measurement of the methylene blue color at a wave length of 650 millimicrons.

A comparison of various methods for determination of sulfide in oxidized sulfate black liquor is given by Collins (94).

The addition of malonic acid as a sequestering agent and gum arabic as a stabilizing agent permitted the photocolorimetric estimation of copper in surface waters by the color reaction with dithio-oxamide (380).

The dithizone method for the determination of copper was modified for use on sewage and industrial wastes by Swope, *et al.* (348). After destroying the organic matter by wet combustion with nitric and sulfuric acids, the copper was complexed with dithizone at controlled pH and extracted with CCl_4. The optical density of the color complex was measured in a photometer using a green filter (510 millimicron wave length) and referred to a calibration chart. The method was recommended for copper in amounts of 0.04 to 14 p.p.m. The standard deviation of the method, on 12 to 15 samples of sewage containing 0.2 to 0.3 p.p.m. copper, was 0.02 to 0.03 p.p.m.

Strandskov, Marks, and Horchler (345) have shown that the residual chlorine test on sewage and sewage effluents by the phenylarseneoxide-amperometric titration method correlates well with the bactericidal results, as compared to the poor correlation with the ortho-tolidine residual. The method consisted of adding a known excess of phenylarseneoxide followed by KI; I liberated by residual chlorine reacted with phenylarseneoxide; the pH was reduced to 2.5 with HCl and the unreacted phenylarseneoxide was titrated with standard iodine to an amperometric endpoint.

Palin (286) differentiated free chlorine, monochloramine, dichloramine, and trichloramine from each other. Free chlorine or free chlorine plus ⅔ of trichloramine was obtained by titrating a sample containing neutral orthotolidine and sodium hexametaphosphate with standard ferrous solution until the blue color was discharged; KI was added, and the titration continued to determine monochloramine. To the same sample, dilute H_2SO_4, followed by $NaHCO_3$, was added and the titration continued to determine dichloramine. Trichloramine was determined on a separate sample by extracting with chloroform.

Mahan (242) assembled an amperometer for use in determining the endpoint of residual chlorine titration. A sample of water was titrated with a standard solution of arsenite. The results of three readings (one having excess arsenite and two deficient in arsenite) are plotted to locate the endpoint for free residual chlorine. The total residual was determined by adding KI to the sample before titrating with arsenite, as in the case of free chlorine residual. In the presence of substance having appreciable iodine demand at low pH, the total residual may be in some error.

According to Trakhtman (359), active chlorine must be determined at the natural pH of the sample without acidification, as adjustment of pH changes the active Cl content.

A review of the most important advance in methods of water analysis during the past 5 years was made by Love (238). The review covered tests for Al, Fe, Ca, Mg, Na, K, Cu, Zn, Pb, Mn, NH_4, B, Se, SiO_2, SO_4, PO_4, Cl, F, CO_2, Cn, Cns, NO_2, NO_3, Br, alkalinity, hardness, residual chlorine, D.O., B.O.D., dissolved solids, organic substances, turbidity, and odor.

The determination of iodine, dissolved oxygen, and "active chlorine" based on the photometric estimation of iodine in a solvent extract was reported by Kulenok (224). The iodine was extracted from water with several portions of CCl_4 or $CHCl_3$. Errors of 1 to 5 per cent were reported in the 1 to 0.2 p.p.m. range, respectively. The D.O. was determined by extracting the iodine liberated in the Winkler procedure. Errors within 0.3 per cent were reported for the 8 to 12 p.p.m. range. The "active chlorine" is converted to I by addition of KI to samples buffered at pH 4.5 before solvent extraction. In the absence of oxidizing agents other than "active chlorine," solvent extraction of acid solutions was possible with less control of pH.

The procedure for the field test for D.O. was as follows: fill 100-ml. gas-sampling bottle with usual precautions; add required drops of $MnSO_4$ and alk-KI-azide, shake, and allow precipitate to settle; use a rubber bulb on pipette to withdraw quickly 50 ml. of clear liquor, followed by quickly adding the required acid and 10 or 20 ml. of CCl_4, shake, or add 20 ml. CCl_4 to inside of bottle allowing clear liquor to overflow, followed by the required drops of H_2SO_4 to acidify. Shake and determine iodine in extractant photometrically in the laboratory. The accuracy was reported to be within 10 per cent in the range from 1 to 10 p.p.m.

A colorimetric method for minute concentrations of D.O. (102) was compared to the potentiometric method developed by Perley. The modified Winkler method uses alk-$MnCl_2$, HCl, and o-tolidine to yield the yellow color of chlorinated o-tolidine. The method was somewhat more reproducible than the potentiometric test in the lower levels of the range 0.08 to 0.003 p.p.m.

The use of dropping mercury electrode for the continuous measurement of dissolved oxygen in flowing water is described by Spoor (334).

Tannin interference in the D.O. determination is reported by Sheets (324). Tannin interference, present in wastes from the paper and pulp in-

dustry and the tanning industry, seriously affects the determination of D.O. The interference is due to the reaction between tannins and iodine. No satisfactory solution is suggested.

Martin (243) reports the use of 4-aminoantipyrine as a reagent for the colorimetric estimation of phenol in water and salt brines in the range 0.2 to 2 p.p.m.

A new indicator for the determination of carbonate alkalinity was proposed (352). The indicator was di-Na 4, 4-bis (4-amino-1-naphthylazo)-2, 2'-stilbenedisulfonate. Its preparation was described and, as it hydrolyzes readily in water, it was made up in acetone. As it was susceptible to chlorine, one drop of 0.1N $Na_2S_2O_3$ was added. The color change was from pink to blue.

Control tests on the determination of calcium using the principles of Chan's urea hydrolysis technique were made by Ingols and Murray (192). Photomicrographs and results showed that the calcium more readily precipitates in large crystals when a sample acidified to pH 1.0 was treated with ammonium oxalate and urea, and then boiled.

Studies on the newer lithia-silica types of glass electrodes for pH meters showed a very rapid response to wide changes of pH in buffered solutions (291). The pitfalls of inaccurate measurements due to improper washing of electrode, mixing the solution, and allowing the electrode to dry, were evaluated and discussed.

A semi-micro method for the determination of nitrogen in sludges is described by Klein (212).

Sedimentation

Schmitt and Voigt (319) describe a new two-story sedimentation basin at the Dalecarlia filter plant of the Washington, D. C., aqueduct. It has a total length of 776 ft. in the direction of flow of water, 316 ft. in the lower story and 460 ft. in the upper; a width of 138 ft.; and a depth of 17 ft. in the lower story and 15 ft. in the upper. Water from the lower story will pass vertically to the upper story through seven large openings 17 ft. 6 in. by 14 ft. 9 in., located at the far end of the basin. Settled water in the upper basin then flows in a reverse direction to the outlet ports. The total capacity is 12.074 m.g., giving a theoretical detention period of 5.4 hr. and an average velocity of 2.4 ft. per min. at nominal plant rating. It is planned to remove settled sludge from the basin at intervals by draining, and flushing with high-pressure water streams. No mechanical cleaning equipment is installed.

Moore, Smith, and Ruchhoft (264) described detention period tests made on two circular sedimentation tanks at Elizabethtown, Ky., by the salt dispersion method. These tanks, having theoretical detention periods of 2.25 and 1.78 hr., respectively, had actual periods of only 1.38 and 1.22 hr. The overflow rate in both tanks was 820 g.p.m. per sq. ft.

Grant (146) described a grit chamber at Columbus, Ohio, where air is used to keep the organic matter in suspension while allowing the grit to settle. The chamber, 83 ft. long by 44 ft. wide, is built very much like a spiral-flow aeration tank with a longitudinal channel along the bottom into which the grit is swept by the rotary motion of the sewage. The grit is removed from the channel by clam buckets.

Results of the performance of a Vacuator are reported by Logan (237). It averaged more than 40 per cent removal of suspended solids from sewage containing cannery wastes. Scum formation on the clarifier surface was controlled.

McLachlan (250) reported scum formation on primary sedimentation tanks receiving waste activated sludge from soluble nitrates from the manufacture of white lead. Reduction of nitrates causes blanket rising of the waste activated sludge. Nitrate nitrogen con-

centrations in the sewage due to this source are as high as 1,000 p.p.m., although rising of sludge will occur with as low as 5 p.p.m. nitrate nitrogen. Chloride of lime application of 230 p.p.m. to waste activated sludge is recommended to control sludge rising and scum formation.

Chemical and Mechanical Treatment

Williamson (386) describes a chemical precipitation plant using calcium carbonate obtained as a waste product from the local water softening plant. The plant employs what is known as the "Daytona Beach Process." Pilot plant experiments indicate an over-all B.O.D. removal to be expected of 70 to 80 per cent with 1-hr. detention period in a specially designed combination coagulation and sedimentation basin.

Chemical treatment of sewage containing a large proportion of textile wastes was studied by Lumb and Barnes (240) in Halifax, England. The chemicals used were chlorinated copperas with and without sulfuric acid and ferric chloride and ferric sulfate. Results obtained from chlorinated copperas differed only slightly from those with ferric chloride and ferric sulfate. Chlorinated copperas removed more impurities than sulfuric acid. A small amount of chlorinated copperas with pH adjustment by sulfuric acid brought about good clarification and is more economical than chlorinated copperas alone. Chlorinated copperas, either alone or in conjunction with sulfuric acid, removes not only colloidal and non-settleable solids but also some impurities in true solution.

Hurley and Lester (187) reported on the full-scale mechanical flocculation of sewage at Coven Heath Works of Wolverhampton, England. It was found that by using a part of the settling tank capacity for mechanical flocculation the quality of tank effluent was improved by 20 per cent. Mechanical flocculation of filter effluents is considered desirable on the basis of some laboratory experiments.

Mechanical filtration of trickling filter effluents through sand and anthracite was reported (377). The sand had an effective size of 1.3 mm. and a uniformity coefficient of 1.6, whereas the anthracite had an effective size of 0.8 mm. and a uniformity coefficient of 2.6. Before the loss of load increased to 8 ft., the anthracite filter passed 2,400 gal., and the sand 2,900 gal., of effluent per square foot. Continuous filtration at the rate of 100 gal. per sq. ft. per hr., and back-washings every 24 hr., irrespective of the loss of load, gave unusually high quality effluents, but after 5 weeks of operation the surface of the filters clogged and the loss of load was 30 ft.

Similar work on the rapid sand filtration of trickling filter effluents is reported from South Africa by Vosloo (373). The provisional basis of design of an actual plant was filtration at the rate of 120 gal. per sq. ft. per hr., with an expected back-wash water of 5 per cent of the total flow.

Biological Filters

Control of Filter Flies with Synthetic Insecticides

Control of filter flies continues to hold the attention of filter plant operators. McLachlan and Hogg (241) report that gammexane is the most convenient, effective, and economical treatment they have experienced. Dosages used varied from 0.1 to 0.5 p.p.m. in the sewage applied for periods of 6 to 24 hr.; fly control over the following 21 days was obtained. Hood (179) found that DDT in concentrations of 12 p.p.m. applied for 2 hr. gave about 95 per cent control of *P. albipunctatus*, but failed to control *P. alternata*, even in concentration of 34 p.p.m. for 2 hr. Benzenehexachloride (BHC) in concentration of 600 p.p.m. was found to control all flies for a period of 28 days. The technique of application involved

draining the final tank to leave about 25,000 gal. of water in it, adding BHC to give a concentration of 600 p.p.m., and recirculating the mixture through the filter for 12 hr. No serious effects on filter performance were indicated.

Tomlinson, *et al.* (357) reported that *Psychoda* and *Anisopus* can be effectively controlled by successive application of gammexane at the rate of 16 lb. per acre in the sewage applied. The filters were shut off for 24 hr. after treatment to increase the effectiveness of the insecticide. The insecticide acts quickly and the effect lasts for at least 2 weeks. Some effluents contained a toxic concentration of gammexane (0.03 to 0.06 p.p.m.) when the filters were started on the day after treatment. These results are also reported in the Report of Water Pollution Research (377).

A discussion of synthetic insecticides for the control of insects is given by Davies (98).

Jenkins, Baines, and Hawkes (194) concluded that gammexane was cheaper to control *Anisopus* at Minworth works (England) than DDT. The application of 10 lb. of emulsified extract of gammexane per acre was effective for 3 to 6 weeks. Hand application was slightly better than application to the feed liquor.

Performance and Operation

A study of parallel versus series operation was made by Moore, Smith, and Ruchhoft (264) on a biofilter plant at Elizabethtown, Ky. Their results showed increased efficiency with series operation and with higher rates of recirculation. Average primary filter efficiencies were essentially constant at 50 per cent, over B.O.D. loading ranges from 2 to 6 lb. per cu. yd. (74 to 220 lb. per 1,000 cu. ft.). The range in efficiency, however, varied from 23.0 to 63.7 per cent. When operating in series, the secondary filter showed an average efficiency of 33.0 per cent, with a range of 5.6 to 44.9 per cent. With parallel operation of filters, plant removals of B.O.D. varied from 71.5 to 89.0 per cent and removals of suspended solids varied from 44.9 to 86.9 per cent. During series operation, for the entire plant, B.O.D. removals ranged from 85.2 to 93.5 per cent and suspended solids removals varied from 59.5 to 85.1 per cent.

Keefer (201) reports on remodeling of filters at Baltimore to increase their capacity by 40 per cent. New rotary distributors have been installed over old fixed nozzles. The dual system will allow rates of application varying from 3 to 10 m.g.a.d. Studies on the value of recirculation continue in England. Oliver (282) discusses the value of mixing humus (final) tank effluent with settled sewage prior to treatment on shallow storm-water filters pressed into service because of an emergency. Results have been so favorable that additional shallow filters and settling tanks to serve them are planned for construction.

Further evidence of English interest in recirculation is shown in a paper by Watson and Twine (379). The authors reaffirmed, on the basis of laboratory experiments, that when a nitrified effluent is mixed with settled sewage and allowed to stand the dissolved oxygen disappears first, followed by nitrates. If a sample was reaerated after the action had proceeded well into the denitrification stage, then instead of nitrate and nitrite remaining constant until the D.O. was once more used up, denitrification proceeded at a lower rate than before and the nitrate was reduced even in the presence of D.O.

Operation of a small sewage work by alternating double filtration and by recirculation of filter effluent in England is reported by Mills, Weston, and Gullan (258).

The work under the direction of Water Pollution Research (377) with biological filtration in England has been continued. Alternating double filtration gave effluents of slightly better

quality than single filtration with recirculation with equal rates of application of sewage of 150 g.p.d. per cu. yd. The reconstruction of the Minworth works in Birmingham will be on the basis of alternating double filtration.

The filtration of sewage containing 0.25 per cent by volume of spent gas liquor deteriorated the quality of the effluent only slightly, but increasing the concentration to 0.4 per cent caused some deterioration.

Large-scale tests with enclosed ventilated deep filters (12 to 14 ft.) were reported by Dekma and Krige (101) from South Africa. Comparisons were made with single- versus double-stage filtration. The volumetric dosage on the double-stage filter was 40 per cent higher per unit volume of media (554 g.p.d. per cu. yd.) than on single-stage filters (198 g.p.d. per cu. yd.). The double-stage filter removed 31 per cent more B.O.D. than the single-stage. Similar comparisons were made with alternations of the order of filters.

The results obtained from an experimental high-rate nitrifying filter treating effluent from the activated sludge plant at Epsom, England, are given by Stanbridge and Allen (336). At a loading of 0.38 lb. per cu. yd. per day and a volumetric dosing rate of 990 g.p.d. per cu. yd., 0.19 lb. of oxidized nitrogen was produced per cu. yd. per day, giving a 61 per cent oxidation of the ammonium nitrogen.

Toxic Substances

Pettett and Thomas (292) report that cyanide concentrations of 2 p.p.m. interfere with nitrification, and effluents showed higher B.O.D. values when cyanide equalled 4 p.p.m. However, at concentrations up to 10 p.p.m., 98 to 100 per cent of the cyanide was destroyed by the filter. With 30 p.p.m. of cyanide in the influent, effluent of poor quality was obtained for a time, but the filter gradually recovered under this loading and gave an effluent of acceptable quality.

Sand Filters

Grantham, Emerson, and Henry (147) reported the results of experiments with biological sand filtration of settled sewage to determine the relationship between loading and degree of treatment. The filters were 7.4 ft. by 7.4 ft. in flow and contained different size and depth of sand. It was found that removal of suspended solids was independent of loading rate and temperature, but was somewhat dependent on sand size and depth of bed. Smaller sands and greater depths afforded better removals. The efficiency of B.O.D. reduction is affected by the fact that the effluents give a relatively high B.O.D. because of nitrification. The B.O.D. of the effluent is lower with small sands, deeper beds, and lower loading rates. Higher temperatures give lower residual B.O.D. values, especially with beds of low depth and larger sands. Split dosing gives higher daily loading rates than single daily loading with equal purification. Under Florida conditions, with settled domestic sewage applied in single daily dosage, rates up to 125,000 g.p.a.d. may be employed on sands of 0.25 mm. effective size and up to 150,000 g.p.a.d. on sands of 0.3 mm. effective size without undue surface clogging.

Activated Sludge

Using Barcroft and Warburg manometers to measure the oxygen requirements of activated sludge, Dawson and Jenkins (99) found that the oxygen taken up by washed activated sludge was proportional to the amount of sludge present and to the period of aeration. The liquor in contact with activated sludge has an appreciable demand for oxygen, but washing sludge twice with water reduced the demand to a negligible amount. The optimum range for oxygen uptake was between

pH 7 and 8 and the optimum temperature seemed to be about 28° C. The oxidation-reduction potential followed the oxygen uptake curve more closely than that for dissolved oxygen, suggesting that above a certain minimum concentration, dissolved oxygen had little effect on the rate of oxygen uptake by activated sludge.

Kraus (222) has undertaken to establish quantitative relationships between the physical variables of the activated sludge process and has developed equations to show the relationship between the sludge volume index and the rates of flow in various parts of the process. High aerator solids are desirable, but difficulties usually arise from limited pumping facilities for return and waste sludge. The addition of digester liquor with high solids and poorly settling excess activated sludge to primary sedimentation tanks creates the serious problem of handling large volumes of sludge. Boyce (71) stated that sudden bulking of activated sludge may result from a failure to evaluate properly all factors and to provide reserve biological workshop facilities to meet the unusual conditions. He also suggests that bulking is a phenomenon closely related to sloughing of biological slime from trickling filters.

Operating results from 26 plants studied by Stanley (338) showed that 92.5 to 95 per cent removal of B.O.D. and suspended solids can be expected in properly designed plants. Loading is a major factor in efficiency. He made limited progress in showing the general magnitude of the effect of certain factors, such as the suspended solids concentration in aeration tanks, quantities of air, and aeration contact periods. Edwards (112) discussed loading from the standpoint of sludge age and step aeration. Step aeration adds great flexibility to the handling of heavy organic loads and permits overloaded plants to function properly again. The determination of sludge age permits a rapid analysis of the loading.

More complete information has been published by Okun (281) on the laboratory studies of bio-precipitation using pure oxygen. He observed that, as the efficiency of B.O.D. removal is a function of the weight of volatile matter in the floc and as the use of pure oxygen makes possible the maintenance of a concentration of biological floc more than twice as great as that possible in conventional activated sludge, a plant with only one-fourth the capacity of the conventional system is required. Mohlman (261), in discussing Okun's work, pointed out that the control tests using air also gave excellent B.O.D. removals with loadings comparable to those handled by oxygen. Although the experiments were conducted in an excellent manner, he believed that the laboratory scale was satisfactory for exploring the chemical and biological features of the use of oxygen, but that larger-scale studies would be required to furnish information on the amount of oxygen needed, the loading capacities, and other design data.

After a study of the variable effects of aeration on the settling of activated sludge, Abbott (4) believes that the soluble colloidal matter in effluents is produced by the friction of the gelatinous sludge particles against each other or against some solid object in the aerator, a condition which probably always exists. Activated sludge is under a permanent handicap as compared with biological filtration, and the degree of purification is lower with activated sludge than with filtration.

Mohlman (260) reported that the Zigerli process, which depends on the addition of shredded asbestos to weight the sludge, now requires an average dose of only 1 to 3 p.p.m. asbestos, after an initial dose of 10 to 40 p.p.m. This process is said to produce in 1 hr. an effluent which would require 4 hr. in an identical parallel aeration tank

of standard design. Imhoff (189) stated that asbestos is a good contact material for bacteria. It has the further advantage that it does not require oxygen and is not affected by toxic materials.

To throw more light on the question of whether bacteria are more important than protozoa as purifying agents in the activated sludge process, Heukelekian and Gurbaxani (168) inactivated protozoa in sludge by the addition of methylene blue, silver, and chlorine, by freezing, by high speed mechanical agitation, and by heating the sludge to 50° C. They concluded that protozoa assist in the clarification of the effluent, but that bacteria are more important as purifying agents.

Gould (145) believes that pre-sedimentation is nearly always advisable, as more material is removed in this way at lower cost than at any other stage in treatment. With activated sludge in good condition, only a short period (30 min.) is required for the floc to adsorb most sewage impurities. Settleability of activated sludge seems to improve directly in proportion to the decrease in volatile matter. The period during which the solids are retained under aeration, or the sludge age, is an important factor. This age must be sufficient to reduce the volatile constituents to a point where good settlement results. Return of excess sludge to the primary settling tanks is seldom desirable. Density currents should be considered in the design of final tanks; overflow weirs should be located near the influent end with sludge withdrawal at the opposite end. At Wards Island, the final tanks have been reconstructed to eliminate sludge blanketing and the aeration tanks have been equipped for step aeration to provide for larger flows.

Oxygen demand curves made with a respirometer have been presented by Lamb (230) to show that the correct aeration period is the time necessary to reduce the demand to about one-fourth or one-fifth of the original value. The detention period and amount of air used per gallon of sewage are proportional to the strength and composition of the sewage.

The design of the 26th Ward sewage treatment plant in Brooklyn has been described by Steffensen (339). The two aeration tanks will be 30 ft. wide and provide 3.33 hr. aeration for the average flow plus 25 per cent return sludge. Air will be supplied through fixed porous tubes at 4 c.f.m. per tube, equivalent to 0.5 cu. ft. per gal. for 60 m.g.d. The tanks are equipped for step aeration and sewage may enter the first, second, and third passes. The 8 final tanks are designed for an overflow rate of 1,000 g.p.d. per sq. ft. Sludge will be scraped in the direction of the incoming sewage with the path of the return flights at mid-depth. The effluent will be removed over side weirs near the end of the tank. The Philadelphia Northeast plant (54), which will employ high-rate activated sludge with 2.5 hr. aeration and 0.3 cu. ft. of air per gallon of sewage, will go into operation about the middle of 1950.

According to Edwards, Carpenter, and Margolies (113), the discharge of a moderate amount of scavenger waste with the characteristics of a well-digested sludge had little effect on the operation of the Jamaica (New York City) high-rate activated sludge plant.

Large amounts of grease appeared on the mechanical aerators at the University of Miami plant (355) during the night, but disappeared during the day. More frequent grease removal did not help, but additions of activated carbon remedied the condition quickly.

At Hagerstown, Md. (96), the excess sludge wasted to the primary tanks increased the suspended solids in the primary effluent to a value higher than in the raw sewage. The sludge built up in the aeration system and could not be wasted fast enough. To improve operation, the primary settling tank

capacity was doubled to give a 2-hr. detention period and a new blower was installed to allow 1 cu. ft. of air per gallon of sewage.

The activated sludge plant at Ann Arbor, Mich. (391), has become overloaded and difficulties have been accentuated by the wasting of excess activated sludge to the raw sewage. With the detention period in the primary settling tank reduced to 30 to 40 min., the suspended solids in the primary effluent have increased considerably, throwing an increased load on the aeration system.

Mohlman (260) proposed that the recorded aeration period be based on the volume of raw sewage treated, not including the return sludge, and this be called the "effective aeration period." The use of large volumes of return sludge may amount to recirculation, thus giving unfair advantage to short aeration periods calculated with high rates of return. The use of effective aeration periods would put all plants on a more comparable basis.

Spalling by an oxy-acetylene blowpipe with a 12-in. flame cleaning head was used at the Wards Island and Bowery Bay plants in New York City to remove surface clogging of diffuser plates (39).

The operating experience of the West Middlesex Main Drainage Works (Mogden, England) during the past 11 years is discussed in a comprehensive report by Townend and Lockett (358). No bulking of activated sludge was encountered at any time.

Finch and Wright (125) reported the results of some laboratory work on the flocculation of sewage colloids by activated sludge. By the addition of 3 to 8 per cent of activated sludge he obtained a 33 per cent removal of impurities in 30 min. For unit of time, increased reduction of load is proportional to the concentration of sludge in the mixture. An economic bioflocculation plant should have a capacity of about ½ hr., should use sludge concentrations of the order of 3 to 7 per cent, and should be supplied with fresh, well-aerated activated sludge.

Hill (172) concluded on the basis of laboratory experiments that nickel salts exert a toxic effect on activated sludge either by adsorptive interference and/or actual poisoning of certain essential microorganisms in the sludge. Concentrations of 1 to 3 p.p.m. of nickel definitely inhibit nitrification, but do not affect clarification.

Nolte and Bandt (277), using a substrate of calcium butyrate supplemented with N and P, found that protozoa were initially affected by 5 p.p.m. KCN, from which they soon recovered. Bacteria multiplied vigorously. With 62 p.p.m. KCN the effluent was free of cyanide and butyric acid. At higher cyanide concentrations cyanide appeared in the effluent and at 80 p.p.m. KCN all life was destroyed down to the bacteria. Up to 330 p.p.m. KCN the activated sludge was normally replenished and butyric acid was decomposed. Previously reported difficulties in the biological treatment of cyanide-containing wastes must, therefore, be due primarily to the simultaneous presence of toxic heavy metals and less to the cyanides.

The use of contact aeration for a small community (16,000 g.p.d. flow) is described by Simpson (325). Treating sewage over design capacity, 90 per cent reduction of B.O.D., with an effluent of 10 p.p.m. B.O.D., is obtained.

Imhoff (190) has reviewed activated sludge practice in the United States for the years 1941 to 1947, inclusive.

Chlorination

The applications of chlorination, as an integral part of processes for the treatment of domestic sewage and industrial wastes, are constantly increasing. These uses are of utmost importance in the protection of public health and in the abatement of stream pollution. There is a real need for intensi-

fying researches into the chemistry and biology of chlorination practices; studies recently reported do not meet this need, either in number or variety.

Griffin (150) has reviewed applications of chlorine in sewage treatment, discussing these uses from the viewpoint of maximum efficiency.

In considering the effects of sewage quality and composition on plant operation, Killam (205) recommends prechlorination at up-sewer locations to prevent or minimize septicity. He cites an instance in which the chlorine demand of sewage was increased from 12 p.p.m. up to 30 p.p.m. by detention in an old pump well in the sewer system. This increase would raise the cost of chlorination over $3,000 per year for each m.g.d. of sewage flow.

Recommendations for the safe handling of chlorine are provided in a paper by Henderson (162), which outlines proper maintenance provisions. Four chlorine accidents at water treatment plants are described in this paper, all the result of carelessness or ignorance, and none due to the failure of chlorine containers. One chlorine accident at a sewage treatment plant has been due to the failure of a chlorine cylinder, as reported by Hood (181). The rupture of this cylinder appeared to be caused by internal corrosion. The author makes constructive recommendations for the prevention of such accidents. The yearly overhaul and inspection of all chlorine equipment is discussed by Pollex (293) as necessary preventive maintenance to insure uninterrupted operation.

Research in Chlorination

Effective bacterial reduction, control of hydrogen sulfide production, and other sewage improvements may be accomplished by applying chlorine in amounts less than those required to produce a residual by the orthotolidine test. Stradskov, Marks, and Horchler (345) have presented a method for measuring these low residuals. Their method involves addition of an excess of phenylarseneoxide, potassium iodide, and hydrochloric acid, and the back-titration of the unreacted oxide with standard iodine solution. The endpoint is best determined amperometrically.

Wykoff (394) has reported the results of research to determine the rate of bacterial (coliform) kill in the plant-scale chlorination of raw sewage. He studied contact periods of 1, 5, 15, 30, and 60 min., employing residuals of 0.05 to 6.0 p.p.m. When the initial chlorine residual was greater than 0.05 p.p.m., the medial bacterial kill after 1 min. of chlorine contact was 80 per cent or greater. After 5 min. of chlorine contact, the bacterial kill reached a median of over 99 per cent in all chlorine residual ranges tested.

Eliassen, Heller, and Kisch (117) have reviewed the biochemical reactions responsible for the production of sulfides in sewage. They report that the initial production can be inhibited by applying 1 p.p.m. of emulsified ortho-dichlorobenzene (Cloroben). The treatment reduces sulfide production by about 75 per cent for 18 hr. at 37° C., and thus might be used to keep sewage in a relatively fresh state during its passage through a sewer system. A pertinent discussion of the nature and growth of sewer slimes has been published by Beardsley (55). The suppression of such slimes is desirable, he points out, because they are implicated in the rapid production of sulfides; the sulfides exert a high chlorine demand, each part of sulfides requiring the application of 15 or more parts of chlorine to the sewage. He has found surface treatment of a cleaned sewer with Cloroben to inhibit slime formation for one year.

Experimental work conducted by Water Pollution Research (377) with chlorination of effluent on the destruction and after-growths of bacteria showed that with addition of chlorine lower than the demand the bacterial

kill depends on the percentage of chlorine demand satisfied, as well as on the concentration of chlorine added. With small residuals 96 to 99 per cent reductions were obtained with 15-min. contact. With increasing contact time the kills increased. After reaching a minimum, the bacterial numbers increased again with increasing time and exceeded the original numbers. Increasing the initial concentration of chlorine prolonged the period required to regain the original level of bacterial numbers.

Incorporation of a small volume of gas liquor in peptone water containing a mixed culture of bacteria resulted in a greater destruction of bacteria and prolongation of the time before aftergrowths occurred. Cyanogen chloride, in contrast with chlorine, had a less pronounced effect on bacterial numbers, but had a longer period of inhibitory effect. There was also a longer period of suppression of the aftergrowths.

Applications of Chlorination

During 1949, 13 plants were in operation to treat 447 m.g.d. (41 per cent) of the New York City sewage flow. Chlorination is employed in 8 of the plants (398). Construction of a new plant employing the activated sludge process is underway to replace the old primary treatment plant at the 26th Ward location (339). Chlorination will be employed for disinfection and for sludge thickening operations.

Chlorination is now required at all new sewage treatment plants in Connecticut, even though bathing or shellfish cultivation are not directly concerned (244). In Rhode Island, the proposed Blackstone Valley treatment works is to serve a municipal area of 75 sq. mi. Six treatment plants are to handle sewage and industrial waste, employing primary treatment and chlorination (83). In the Nut Island plant, under construction to treat sewage from the city of Boston, primary treatment and chlorination will be provided (60). Capacity for feeding chlorine will be 3 tons per day, and the long outfall sewer will be utilized for contact time.

The large central sewage treatment plant (250 m.g.d.) planned for the Allegheny County (Pa.) Sanitary Authority will employ preaeration, sedimentation, and chlorination (225). Chlorine demand will be one of the factors determining charges for industrial waste treatment. Both prechlorination and postchlorination are included in the primary treatment project planned for the city of Harrisburg, Pa. (290).

Three primary treatment plants utilizing both prechlorination and postchlorination protect fisheries and beaches in the Hampton Roads, Va., area (70).

Chlorination for Disinfection

Primary treatment and chlorination, throughout the year, provide the degree of treatment required at the Detroit sewage plant, where the daily flow averages 346 m.g.d. (38). To satisfy 66 per cent of the chlorine demand, in 1947, required 4.4 p.p.m. (2,342 tons) of chlorine; the coliform removal accomplished was 79.68 per cent.

In the same year, primary treatment and chlorination were used at the Cleveland Westerly sewage plant (52), where the flow averages 33 m.g.d. Prechlorination was employed for 87 days at an average 8.71-p.p.m. rate of application, and postchlorination for 70 days at a 6.10-p.p.m. rate. An average residual of 2.12 p.p.m. was maintained in the final effluent. At the Cleveland Easterly plant, postchlorination follows activated sludge treatment (136) and was employed for 91 days during the bathing season. A chlorine residual of 0.7 p.p.m. was maintained by chlorination at a 4.4-p.p.m. rate of application. The total bacterial reduction accomplished was 99.35 per cent,

and the reduction in presumptive *B. coli* was 99.89 per cent.

Effective prechlorination for odor control is essential at the Fort Wayne, Ind., activated sludge treatment plant (183). Chlorination is in two stages: part is added to the main interceptor at a station about 1 hr. ahead of the plant, the remainder at the plant proper. A program chlorinator is employed at the up-sewer location and an automatic chlorinator at the plant, the function of the latter being to maintain about 70 per cent satisfaction of the chlorine demand. About 90 tons of chlorine are applied during the summer season. The treatment accomplishes control of odors and has no deleterious effect on the activated sludge process.

Postchlorination is required for 5 summer months each year at the Baltimore, Md., sewage plant to reduce the bacterial load on the receiving stream (200). The major flow of sewage is treated on trickling filters and the remainder in activated sludge units. The mixed effluents are chlorinated to maintain a residual of about 0.5 p.p.m. after 10-min. contact.

An activated sludge treatment plant at Clewiston, Fla., is to utilize automatic chlorination (288). The control is to be accomplished by the head over a discharge weir in the end of the chlorine contact unit. Automatic postchlorination is also provided in a new plant at Ingersoll, Ont. (13). This plant includes prechlorination facilities for odor control and return sludge chlorination for bulking control.

Capacity for feeding 18 tons of chlorine per day is provided for the new Hyperion activated sludge treatment plant under construction at Los Angeles (34). An application rate of 10 p.p.m. is contemplated in prechlorination for odor control 4 months each year, and a postchlorination rate of 3 p.p.m. for disinfection 6 months each year.

General discussions of the theory on which the use of return activated sludge chlorination (36) and sludge thickening chlorination (35) is based have been published. The first use is considered effective when bulking is due to fungus growths which can be controlled without destroying beneficial plankton. The second use depends on the inhibition of gas-forming organisms in order to reduce convection currents in thickening units.

Chlorination for Industrial Waste Treatment

The chlorine method for treating industrial wastes which contain cyanides is being widely adopted as the preferred method (164). This method requires the application of sufficient chlorine to maintain a residual of free available chlorine after 30 min. of contact, and the maintenance of a minimum pH value of 8.5 throughout the contact period.

Cyanide wastes are treated by this method at the Western Electric Co. plant, Allentown, Pa., using chlorine and caustic soda (138). At the Talon, Inc., plant, Meadville, Pa., chlorine and lime are used (33). At the National Carbon Co. plant, St. Albans, Vt., chlorine and caustic soda are used (385). At the General Motors Corp. plant, Sandusky, Ohio, provision has been made to use this method when such wastes are present (366). It is reported that one chemical manufacturer is now operating 5 chlorine oxidation plants (3 employing acid treatment and 2 alkaline treatment) for the elimination of odorous and toxic compounds from wastes (296).

A method developed by British investigators is applicable to the destruction of simple cyanides and complex cyanides of zinc, cadmium, and copper; but not to solutions containing nickel. Eden, Hampson, and Wheatland (110) have reported this application; calcium hypochlorite is employed at pH 11, the reaction produces cyanogen chlo-

ride, and the CNCl hydrolyzes without further absorption of chlorine.

The toxicity of chlorinated sewage effluents which contain gas works liquors is discussed in the 1947 report of the (British) Water Pollution Research Board (28). Cyanogen chloride is formed when these sewages are chlorinated for disinfection; a minimum concentration of 0.08 p.p.m. of cyanogen chloride is toxic to rainbow trout. Allen, Blezard, and Wheatland (11) have shown the cyanogen chloride to be produced through the reaction of chlorine on thiocyanates contained in the gas works liquors. They report this reaction to occur when chlorine is applied in an amount less than that required to produce a residual in the ortho-tolidine test. Increasing amounts of applied chlorine show an increasing straight line relationship with toxicity. The addition of excess chlorine (presumably an amount required to produce a residual in the ortho-tolidine test) causes a marked loss of cyanogen chloride.

Among research projects initiated by the Sanitary Water Board of Pennsylvania is one to develop methods for treating wastes from small slaughterhouses (257). A small meat packing waste treatment plant in Texas is described by Huppert (186) to employ coagulation with sulfuric acid and alum, and to apply chlorine dioxide for control of odors as well as for effluent disinfection. The chlorine dioxide is produced from calcium hypochlorite and sodium chlorite. Operating costs are given as about 26¢ per 1,000 gal. treated.

The chlorine demand of industrial wastes is one of the factors involved in the determination of rate charges when such wastes are treated in a municipal plant employing chlorination. Symons (349) reports the chlorine demand factor to be included in the rates of Buffalo, N. Y., and New Brunswick, N. J.; and in the Wright formula, the California formula, and the Allegheny County formula. Riddick (302) has suggested broad rules and regulations to cover the discharge of trade wastes into the Westchester County, N. Y., sewer system. Among these is the requirement that "All effluents from hospitals shall be chlorinated so as to maintain a free chlorine residual (after 30-min. contact) of at least 10 p.p.m." Activated sludge plant effluent is sold by the city of Big Springs, Tex., to a petroleum refinery. Whitney (384) states the contract provides that the city shall chlorinate the effluent to maintain a chlorine residual of not less than 0.05 p.p.m. after a 15-min. contact period.

Chlorine Products for Sewage Treatment

Odor correction is especially important at the Phoenix, Ariz., plant in order to prevent nuisance (14). Ferrous chloride (produced from scrap iron and chlorine) is applied at up-sewer points, and ferrous sulfate is applied at the sewage treatment plant.

Preliminary tests of up-sewer application of Cloroben showed promising results in the Oklahoma City sewer system (15). Treatment of raw sewage at the Springfield, Mo., plant by Cloroben indicated this treatment could control odors where sewage was exposed at the bar screen, but that no effective odor reduction was accomplished where the principal liberation of odors occurred at the trickling filters and sludge drying beds (132).

Promising results were obtained by Tims (356) in the use of activated carbon for pretreatment of septic sewage at the Key West, Fla., plant. Plant-scale studies showed reductions in odors, septicity, and chlorine demand could be accomplished by this means.

Sludge Digestion

Construction

Vaseen (370) describes a type of Imhoff tank which is divided longitudinally into two separate sludge col-

lecting chambers. The division wall is located beneath a longitudinal slot gate, which can be switched readily by the operator, thus diverting sludge to either side of the division wall. Several of these devices have been installed. The author claims better sludge digestion and gas production with savings in digestion space and sand-bed area.

The world's largest installation of separate sludge digestion tanks is in the Hyperion plant serving the City of Los Angeles (24). This installation comprises 18 primary and secondary sludge digestion tanks, each having an inside diameter of about 111 ft. The total sludge capacity of all tanks is about 6,000,000 cu. ft. (45,700,000 gal.). The tanks are of prestressed concrete with reinforced concrete domes. The walls are wrapped with wire stressed to 130,000 to 150,000 p.s.i. and then coated with gunite. The concrete walls inside the wire wrapping are 20½ in. thick—nearly three times the thickness required for strength—for easier construction and more effective heat insulation.

What the lack of proper digester construction means to a plant operator is outlined by Lacy (229). At Lockport, N. Y., the plant site rests on clay and no piling was provided in the foundations. The tank walls settled and the floors buckled, resulting in damage to sludge-collecting and scum-breaking mechanisms, as well as to piping.

Heating

This subject was briefly summarized by Greene (148). He first analyzes the heat requirements and then lists the several heating systems which have been used. In referring to the use of the ejector type of heater and sludge circulator, the author overlooked the successful use of this device in Denver. Cohn (92) condenses and analyzes the "Round Table" discussions of sludge heating and circulation that were reviewed previously. Baffa (49) sets forth a description of the best-known types of external heat exchangers and deals with the fundamentals of the theory and practical use of hot-water heat exchangers.

Operation

Haseltine (158) discusses preparing sludge for digestion and digestion practice itself. These articles contain a wide range of useful information for operators, including sludge thickening prior to digestion, the reasons for digestion, its biochemistry, its nature, and its chemical and mechanical control. In dealing with temperature control, the author shows the various methods used and his preference for external heat exchangers. The method advocated for determining the alkalinity of digester supernatant is neither as simple nor as rapid and accurate as that used by McNamee.

In the name of the representatives of the Connecticut State Department of Health and numerous sewage treatment plant operators of that State, Giles (137) handles the question of liming sludge digesters very neatly. He shows what poor liming practice is and enumerates the conditions that permit good digester operation without and with proper liming.

Scum

The problems of scum formation and its control are highly important and the solution of these problems is closely related to the successful operation of basic sewage treatment processes (305). A condensation and analysis of this subject is given by Cohn (93).

Rudolfs and Logan (308) list the stages through which scum formation passes and summarize the results of investigations made on some factors influencing the digestion of scum. They show that lighter materials separate from digesting sludge, float, and gradually compact, resulting in dehydration of the scum layer, which in turn retards digestion. Mixing devices and

certain chemicals aid in wetting and softening the scum, which in turn aids in its digestion.

Cleaning Digesters

Different reasons exist for cleaning digestion tanks and scum formation plays a role. Hoot (182) briefly notes the beneficial effects on heat transfer after cleaning the digesters and descaling the heating coils in the Ft. Wayne, Ind., sewage treatment plant. At Marion, Ind., Backmeyer (47) shows it wasn't so much the question of heat loss through scaling, as loss of digester capacity through compacted solids deposits, some of which came from the scum. The immovable deposits left in the primary digester after draining the tank contents were of two types: (a) a thick layer of fibrous trash that had been top-scum and (b) a heavy floor deposit of grit that had settled from the fluid portion of the tank contents. The deposit left in the secondary digester after complete draining was an immovable jelly-like mass containing almost 22 per cent solids with a volatile content of about 40 per cent. This deposit evidently developed 5 or 6 years previously when the secondary digester was used for concentrating the digested solids leaving the primary digester, by elutriation in the secondary digester.

Gas Utilization

Four important phases of the subject of using gas engines in sewage treatment plants are presented and discussed by Hundley (185); namely, high temperature cooling, torsional vibration, safety controls, and supercharging. Under these headings the various methods of obtaining the best performance with a minimum of shock and wear on the equipment are logically developed.

In his article on the electrification of sewage treatment processes, Greiff (149) also deals with this subject. He lists the requisites for the economy of using gas engines for producing power and supplying the energy requirements in sewage treatment. He shows that because of its high economic yield the popularity of the dual-fuel engine is growing.

Crooks (97) briefly describes this type of engine, the need for it, its development, present status, and advantages for sewage treatment plants. Four excellent coordinate graphs show the comparative savings resulting from its use.

Scott and MacGillivray (321) relate why an average of 183,000 cu. ft. of 635-B.t.u. gas is wasted daily at Winnipeg. The Hydroelectric Department of the city itself supplies the Greater Winnipeg Sanitary District power at the rate of 0.625¢ per kw.-hr. During a 3-week period in the spring the sewage becomes so dilute that barely enough gas is produced for normal plant heating purposes. This factor places the balance in favor of the present arrangement for power. This appears to be an argument in favor of using dual-fuel engines in such plants. However, the latest proposed use of the waste gas at Winnipeg is in the firing ovens of a new ceramic manufacturing plant located near the sewage treatment plant.

Industrial Waste

In continuation of their thoroughgoing and informative summary of laboratory and pilot plant studies involving the aerobic treatment and anaerobic digestion of compressed yeast plant wastes, Rudolfs and Trubnick (310) (311) (313) (314) show that such wastes are readily amenable to a considerable degree of purification by such combined treatment. The B.O.D. reduction by proper 24-hr. digestion is as high as 60 to 70 per cent. Their report on 5 years of investigations with a pilot plant two-stage digester of 28,000-gal. capacity shows a high degree of correlation between results obtained in the laboratory and this plant. In

their laboratory report, the authors conclude that the degree of purification of such wastes is high enough to warrant large-scale operation; in their reports on pilot plant digestion they present valuable information on quantities of sludge required for efficient digester operation, volume of sludge produced, other data sufficient for planning full-scale treatment, and a treatise on the application of the basic principles disclosed by their investigations.

The treatment of wool scouring wastes has been discussed to some extent in the 1949 literature dealing with industrial waste. However, in listing the various treatment methods not much attention has been devoted to digesting such wastes. Singleton (327) lists the results of pilot plant investigations involving two-stage digestion of such wastes in experimental digesters of 500-gal. capacity. In spite of handicaps encountered, the results obtained indicate that anaerobic digestion of such wastes presents a possible practicable method of dealing with them.

In listing the results of laboratory experiments on the digestion of strawboard waste, Gehm and Morgan (135) describe a continuous system proposed for plant-scale anaerobic digestion of such material. It consists of three successive compartments operating in series and placed along a common mechanically operated stirring device. Trubnick (361) discusses the principles involved in the device, digestion in general, and the improvement gained by agitation. Except for the mechanical agitator employed, the principles involved in the series operation, continuous seeding, and recirculation of seed, the device is somewhat similar to the well-known, high-rate, multiple-stage digester of Rawn, Banta, and Pomeroy.

Digesters will evidently stand a heavy shock load of condensed milk with no noticeable ill effects. Backmeyer (48) gives a good example of this in relating what happened when 11,000 gal. of condensed milk was dumped during a 24-hr. period into the ground garbage being fed to the digesters at the Marion, Ind., treatment plant. The resulting gas production was rapid and spectacular.

Theory and Mechanism

Buswell and Sollo (335) had previously made the observation, by the use of tracer experiments with C^{14}, that in methane fermentation, when acetate is decomposed in the presence of labeled CO_2, relatively little of the isotope is recovered in the resulting methane, and had concluded on this basis that methane is produced mainly from acetic acid and only slightly from CO_2. Stadtman and Barker (335), using C^{14}-labeled CO_2 and acetic acid, have shown that methane is derived mainly from the methyl group, whereas the CO_2 is derived from the carboxyl group. A little CO_2 is converted to methane. The methane formed in the fermentation of methyl alcohol, however, is derived from CO_2 and not from alcohol or acetic acid.

Sludge Disposal and Utilization

Vacuum Filters

The Minneapolis-St. Paul Sanitary District has been a pioneer on studies of vacuum filter cloth washing. Comments by Superintendent Mick (254) in the 15th Annual Report on plant operation show that it is now considered most economical to wash the filter cloth at hourly intervals, instead of continuously as originally contemplated. Continuous washing of the cloth during filtering operations has caused cloth blinding sooner and excessive wear of the cloths.

Jepson and Greene (195) presented the results of extensive semi-scale experiments on the dewatering of activated sludge by coagulation with chlorinated copperas and vacuum filtration. They obtained a cake of 83.5 to

89.8 per cent moisture content. The output of the cake averaged 0.74 lb. dry solids per sq. ft. per hour with an average dosage of chlorinated copperas of 19.1 per cent. Aeration of the activated sludge prior to filtration had little effect on the output, but reduced the amount of chemical required. The filtration of elutriated digested sludge produced a cake with a moisture content of 72 to 75.9 per cent. An output of 1.35 to 1.72 lb. dry solids per sq. ft. per hour was obtained with an average copperas dosage of 13 per cent. More chlorinated copperas is required than ferric chloride to produce the same results with a lower filtration rate, but it is cheaper than ferric chloride.

Jepson and Klein (196) also investigated the heat treatment of sludges at high pressures to condition the sludge prior to filtration to obtain a sludge with a higher percentage of solids. The solids content of the heat-treated sludge depends largely on the solids content of the original sludge, but also on steam pressure applied and the time of application. The heat-treated sludge settles readily. The separated liquor is foul and may contain up to 35 per cent of the original solids and up to 59 per cent of the original nitrogen content. The densified sludge filters very readily and can be dewatered readily on sand beds or by mechanical means.

Sludge drying with roto-louvre dryer is discussed by Goldstein (139).

Incineration

The incineration of liquid raw sludge at Ashland, Ohio, was reported by Laboon (226). Two sludge storage tanks are used to concentrate raw sludge from a population of 15,000. The sludge was concentrated to 85 per cent moisture and had a volatile matter content averaging 75 per cent. The presence of 5.5 per cent iron in the furnace slag is believed an indicator of aid in the sludge's concentration. To consume the sludge, 3 gas burners using 1,100-B.t.u. per cu. ft. natural gas were employed. Incinerating troubles have included shear pin failures and iron slag in the furnace. The author concludes that the cost picture is favorable and that no highly technical skill is needed. However, improvements are cited as possible and better odor control is needed. It is to be noted that the sludge concentration is unusually high, that a high B.t.u. gas is employed, and that mechanical troubles have been encountered.

Utilization and Recovery

Houston, Tex. (362), is joining the cities which produce dried sludge for fertilizer. In 1950 it is planned to complete a sludge dewatering and drying plant at the North Side plant at a cost of $1,394,000. Raw primary and excess activated sludge from two plants (one of which is the North Side plant) will be vacuum filtered with ferric sulfate, and heat dried. The estimated average daily flow from these plants in 1970 will be 68 m.g. and the connected population 776,000. Peak sludge loads in excess of 61 dry tons per day will be lagooned. The anticipated revenue is $268,000 per year, based on the sale of 21,000 tons of fertilizer yearly at an average bulk sale of $12.25 per ton. The city has been selling sludge fertilizer at $17.25 per ton, but a more conservative figure has been used for estimates, inasmuch as there is no complete assurance that this latter price will prevail. The existence of a stable market for sludge fertilizer within a reasonable distance from Houston resulted in the adoption of this method of sludge disposal over 11 other methods considered.

Under the United Nations Relief and Rehabilitation Administration, a demonstration night soil fertilizer plant was built at Shaoyang, China (344). Night soil is a major source of organic fertilizer in China, but because of local practices, pollution of food and

water occurs, as well as a loss of nearly half the original nitrogen. The plant was designed to handle 30 tons of organic matter daily from a tributary population of 85,000. The organic matter used included human excrement, garbage, straw, bone meal, and wastes from industry.

The papers presented at a conference on the utilization of sewage sludges in South Africa are published by the Institute of Sewage Purification. Abbott (1) discussed the problem from the standpoint of origin and methods of disposal. Krige (223) made a plea for the agricultural utilization of sludge and emphasized the importance of composting after digestion and dewatering. Other papers dealt with the health aspects of utilization of sludge, which are presented in another section of this review.

A scheme of application of wet digested sludge to fields sown to hay and the utilization of the digester gas for artificial drying of the hay is to be put in practice in Blackburn, England, as described by Leigh (233).

In France, according to Dufournet (106), a commission came to the conclusion that no rapid progress could be made in sewage treatment unless certain by-products were recovered, particularly effluent for irrigation, sludge for fertilizer, and gas for municipal use.

Recovery, processing, and marketing of by-products in Bradford, England, is discussed by Hillier (173). The sewage contains large quantities of wool scouring wastes producing a sewage with 1,200 p.p.m. suspended solids and 640 p.p.m. of grease, which is processed and recovered.

Van Vuren (369), in a recently published book, advocates composting of wastes for the manufacture of organic soil food. The success of this scheme in South Africa is described. The emphasis is on hygienic and economic methods of production.

Detergents

Knox, *et al.* (215) have shown that several cationic detergents kill *E. coli*. The detergents kill or inhibit in proportion to the detergent-bacterial ratio and not according to detergent concentration. Certain enzymes of *E. coli* can be inhibited by detergent-protein ratios which are bactericidal for the intact cells. The specific inhibition of such detergent-sensitive enzymes can account for the metabolic inhibition, death, and increased permeability of bacteria.

In a symposium held in England, the problems arising in sewage disposal plants from the increased use of detergents were discussed (350). Hillier and Campbell discussed the nature of synthetic detergents, pointing out that they have certain advantages over soaps in the scouring of textiles and wool. Lumb and Barnes stated that substantial usage of the synthetic detergents will result in considerable difficulty in plants treating domestic sewage. The detergents will not react with the emulsified impurities and precipitate them as is the case with soaps; as a result the impurities will pass to the secondary treatment units, increasing the load and the quantity of secondary sludge, whereas the grease content of the primary sludge will be lower, with consequent lower yields of gas. Sewage containing wool scouring wastes with the use of detergent, when cracked with sulfuric acid, gave low percentages of purification and hence more emulsified liquors are being discharged on the filters, according to Hillier and Beedham. Goldthorpe and Nixon reported that the addition of 25 p.p.m. Teepol X to sewage reduced the amount of sludge formed by precipitation with sulfuric acid by 12 per cent, 50 p.p.m. by 32 per cent, and 200 p.p.m. by 98 per cent, with corresponding increases in the oxygen-absorbed value of the settled liquor. The same detergent had little effect on the settling of activated sludge up to 230

p.p.m. concentration. It lowered the surface tension of the liquid, which was restored by pretreatment with alum. After aeration of the activated sludge, the presence of detergent created a tendency for the sludge to rise. It is suggested that industries using these products should treat their own waste.

Rudolfs, Manganelli, and Gellman (309) conducted laboratory experiments concerning the effect of synthetic detergents on sewage treatment processes. They found that the effects of various detergents were different. The principal indicated effects of the detergents were decreased efficiency of settling tanks; foaming, floc agglomeration, and carry-over in activated sludge units; and reduction in gas production from sludge digestion.

Goldthorpe, *et al.* (140) stated that the increased load passing out of the sedimentation tanks as a result of the use of synthetic detergents may be as high as 30 per cent for domestic sewage and more than 100 per cent for certain industrial sewages. They viewed with alarm the effect of this on the overloading of existing biological treatment plants. The authors predicted that detergents can affect the surface tension, and thereby, the transfer of oxygen. When detergents were added to sewage and precipitated with acid, the supernatant liquor had a higher B.O.D. than the sewage similarly treated but without detergent. Such a supernatant, when treated by the activated sludge method, produced an effluent with a higher B.O.D. than the control sewage.

Degens and Van der Zee (100) reported on the effect of certain detergents on digestion and biological oxidation of sewage. Digestion was not affected, but biological oxidation of sewage was delayed by certain detergents. They concluded, however, that the limiting concentrations for damage by detergents in sewage are so high that during the first years of household use no trouble would result in treatment plants.

Mechanical Equipment

Articles on mechanical equipment are more numerous in the literature of 1949 than for many years past, indicating an increasing appreciation of the value of improvement in such equipment and in the automatic control of sewage treatment processes. Although kitchen waste grinders are not new in the sewerage field, they are coming into increasing prominence and recognition, as is pointed out by Cohn (89) (91). The future of home grinders is predicted by Owen (284), who presents valuable information on their history, status, and performance.

Experience with automatic equipment in the control of chlorine in the treatment of raw sewage at Fort Wayne is described by Hoot (183), who presents charts showing dosage records, together with a discussion of the performance of the equipment. Meters and control equipment in the activated sludge process are described by Pearson (289) in the second of a series of articles on instruments in the control of sewage treatment processes. The first article of the series is devoted to automatic devices for cleaning screens. In the third article he describes meters, gages, and recorders; in the fourth, similar equipment is described for control in sludge gas utilization, together with a description of flame control devices. Contactor pH measurements, elutriation waste water flow meters, and other equipment in controlling sludge elutriation, conditioning, and filtration are described in the fifth, and a description of control equipment in industrial waste treatment comprises the sixth article.

Electrical equipment in the production of power from sludge is described by Greiff (149) in the first of a series of articles on the electrification of sewage treatment processed. Greater detail in the arrangement of the equipment in the pumping station is given

in the second article; pump-control diagrams and electrical pump-control benches are covered in the third; electrical control boards, electrically driven sludge pumps, electrically driven blowers, and explosion hazards are discussed in the fourth. Electronic equipment in the control of sewage treatment plants is described by Fitch (126), who states that control of sewage pumping plants has not advanced beyond the stage of simple float switches. However, at Seattle electronic-type controls are in use that are not found in any other plants of similar importance in the United States.

Magnetic drives for sewage pumps, to be installed at the Nut Island treatment plant in Boston, are described by Meeker (253) as the first of their type to be installed in a sewage treatment plant. Some do's and don't's in the installation of low-lift sewage pumps are emphasized by Angus (44). He stresses particularly the need for short suction pipes and the avoidance of water hammer. The pumping of sewage by compressed air is described and recommended by Parks (287) for conditions near Lake Okeechobee, where electric power outages occur during hurricanes. The dual-fuel engine that uses oil fuel on the diesel cycle, or gaseous fuel with oil-fuel ignition is an interesting advance in the development of power from sewage gas. It is described by Crooks (97). Hundley (185) describes principles of interest concerning internal combustion engines utilizing gas as a fuel.

Knapp (213) (214) describes equipment for sewer cleaning and flushing, catch basin cleaning, and for the inspection of sewers. An especially interesting piece of equipment is the Hydrocrane used for excavating. This device is described also by Brown (75).

A roto-louvre sludge dryer is described by Goldstein (139). Baffa (49) describes the heating of sludge by heat exchangers with special emphasis on the forced, hot-water circulation type of exchanger. Logan (237) describes the Vacuator for the removal of scum from tanks at Palo Alto; Haseltine (158) describes mechanisms for the removal of grit and sludge from grit and sedimentation chambers; and Benas (57) describes an electrically driven, portable sand pumping rig, useful in removing materials deposited in channels, sumps, and tanks.

Among the gadgets in sewage works, Galloway (133) describes an automatic sampling device, a chlorine cylinder rack, a portable digester cover scaffold, and a rig for hoisting equipment around the plant. Edwards (111) describes an air scrubber at the Wards Island plant using diesel oil for odor removal; Mick (254) describes an interesting kink in the maintenance of vacuum filters which functions by means of water pressure nozzles spraying the filters hourly.

Mechanical equipment at Baltimore, according to Keefer (201), has added 40 per cent to the capacity of the plant. The equipment described by him emphasizes particularly sludge and scum removal equipment.

Miscellaneous

The third Manual of Practice of the Federation of Sewage Works Associations, dealing with Municipal Sewer Ordinances, was published (123).

Organization and financing of the Allegheny Sanitary Authority was described by Du Von (108).

Replenishment of ground-water supplies and prevention of salt-water encroachment by spreading sewage effluents on the ground is being advocated for Los Angeles County (31).

In Ridgewood, N. J., Hood (180) is distributing copper sulfate to householders to be placed in flush toilets for the purpose of controlling root growths in sewers.

Owens (283) comes to the conclusion that it will be 20 years before half the dwellings in a community will be

equipped with garbage grinders. When this happens, the sludge load on the sewage plant will be increased by about 10 per cent.

Industrial Wastes

General

A good presentation of some of the problems involved in surveying an industrial waste problem is given by Weston, *et al.* (382). The problems and pitfalls involved in getting representative samples are discussed, together with the types of analyses required and methods of evaluating data. Although the paper deals specifically with the methods required for a survey of a large industry, many of the points discussed are equally applicable to the smaller industrial waste problems.

Mohlman (262) discusses the possibilities of recovery and utilization of materials in the wastes of some of the important industries surveyed by the Chicago Sanitary District, including packinghouse, wool scouring, brewery, distilling, and pulp and paper wastes. Although manufacturers in time come to regard a profitable recovery method an integral part of the industrial process, there still is a field for waste utilization and recovery if the economy of the method is based on the cheapest method of waste disposal and not on direct profits alone. Utilization and recovery of industrial wastes from a biological standpoint is also treated by Buswell (78) in a general discussion of how the control of biological activity can either permit valuable by-product recovery or permit reuse of waste waters in an industrial process.

A symposium (32) on the industrial waste problems in the various states is given in short reports by the chiefs of regulatory agencies from 36 states. The industries causing stream pollution, the extent of the problem, and what is currently being done in each state to prevent pollution are presented. Examples of the treatment of mixed industrial wastes and sewage by the activated sludge process are given by Lamb (230). His investigations show that most industrial wastes are amenable to treatment by activated sludge, provided adequate allowance is made in the design of the plant.

Radioactive Wastes

A booklet (41) on "Handling Radioactive Wastes in the Atomic Energy Program," prepared by the Atomic Energy Commission, presents a simplified discussion of some of the dangers and problems involved in making and using radioactive compounds. Information is also given relative to what is known and being studied in connection with the disposal of radioactive wastes to prevent dangerous air and water pollution. Gorman and Wolman (143) discuss the general problems involved in the disposal of radioactive wastes, with particular reference to the role of sanitary engineers in the radioactive waste disposal program. They conclude that trained sanitary engineers have an opportunity and a responsibility in the field of radioactive waste disposal and that they should be trained in the fundamentals of nuclear physics to understand better the problems created by this new industry. In a similar paper, Gorman (142) again discusses the radioactive waste disposal problem and points out the necessity for special training of sanitary engineers so that their special knowledge in the fields of waste disposal and water supply can be useful to the atomic energy program.

A digest (45) of the proceedings of a special seminar sponsored by the Atomic Energy Commission for leaders in the sanitation and water supply fields deals with all phases of radioactive waste disposal problems. More detailed information and discussion on human and animal radioactive tolerance limits, water and air pollution, and available methods of treating wastes is presented here than in any other available publication.

Ruchhoft (306) discusses the possibility of using a modified activated sludge process to remove radioactive materials from waste waters and concentrate them in the sludge. Laboratory experiments have shown that by using such a process it is possible to obtain a 700-fold concentration of radioactive plutonium in the sludge. Many problems are involved, and tolerance limits for the sludge to radioactivity and concentrations of toxic compounds must be determined before practical applications can be made. Studies are being made to find suitable organic food for such a process when sufficient domestic sewage is not available.

Packinghouse Wastes

Eldridge (115) reports operation of a treatment plant for wastes from a small packinghouse, consisting of a holding tank (to provide 24-hr. operation), a septic tank, and a high-rate filter 14 ft. in diameter and 7 ft. deep, with stone media of 3- to 4-in. diameter hard granite. A rotary distributor applies the settled waste. Results of a 2-day test in September showed reductions of B.O.D. from 2,200 and 1,750 p.p.m. to 750 and 725 by the septic tank, and to 18 and 57 p.p.m. in the filtered, settled effluent. Loadings were 0.77 and 0.54 lb. per cu. yd. per day, with 4.5 and 4.9 recirculations, respectively. The plant, at Owosso, Mich., shows the feasibility of a high-rate filter for this very small slaughterhouse, which kills only about 14,000 lb. per day of cattle, hogs, and sheep.

Chemical treatment, described by Huppert (186), included a surge tank, a flash mixer in which sulfuric acid, alum, and chlorine dioxide was used, settling basins, and sludge digester. The acid reduces pH to 5.5, alum forms a floc, and chlorine dioxide is used for disinfection and odor control. B.O.D. reduction is 50 to 75 per cent. Effluent, when chlorinated, may be used as condenser water when filtered. Cost of chemicals averaged the exorbitant figure of $47.80 per 1,000 gal.

Packinghouse waste treatment at several small plants in Illinois was discussed by Klassen and Hasfurther (211). One plant, at Elgin, uses ferric chloride and gave 61 to 78 per cent B.O.D. reduction. The final effluent B.O.D. ran from 340 to 550 p.p.m. in four tests made in 1948, using 88 to 185 p.p.m. coagulant. A test using ferrous sulfate gave an inferior floc and only 39 per cent reduction.

A smaller plant at Rushville, Ill., does no killing and only prepares meat for sausage making. Wastes are settled, after addition of ferric chloride, then applied to an aerofilter 24 ft. in diameter, 8 ft. deep, and finally settled in a rectangular settling tank. At a loading of 1,850 lb. B.O.D. per acre-ft. per day, the B.O.D. removal was 74 per cent, and over-all 94 per cent, with a final B.O.D. of 35 p.p.m.

A discussion of the disposal of packinghouse wastes was presented by Mohlman (259) before a research conference of the American Meat Institute. Unit losses were defined, also reasonable factors for good and poor operation. History of the treatment processes that have been used was reviewed and efficiencies of various types compared. The practical value of washable high-rate filters was stressed, as a preparatory step. Activated sludge treatment is successful at Chicago because of the large dilution of wastes with sewage.

Treatment of packinghouse wastes with city sewage at Huron, S. Dak., was discussed by Dunmire (107). The packing plant, with an average daily kill of 200 tons, contributes 60 per cent of the flow, with B.O.D. from 380 to 550 p.p.m., added to 40 per cent of sewage with B.O.D. of 210 p.p.m. The plant consists of a primary tank, which removes 70 per cent of the B.O.D. (from 550 to 165 p.p.m.), and 6-ft. deep rock filters dosed at 2 m.g.a.d. Final settling tanks reduce the B.O.D.

to 50 p.p.m., and 19 p.p.m. from a new clarifier, to meet the disposal requirements. The results show the advantage of a diluted waste as applied to normal treatment devices. The primary tank includes a flocculator (without chemicals) and the packinghouse waste is screened.

Wastes from packinghouse operations are discussed in detail by Nelson (274). The sources of wastes are described and suggestions are given for salvage of grease and nitrogen. A plant at Madison, Wis., uses lime to precipitate the stronger wastes and plain sedimentation for weaker wastes. An equalization tank is necessary. Sludge is treated with lime, filtered, and trucked to a waste-disposal area. The effluent is discharged to the municipal plant.

Treatment of wastes from small slaughterhouses in Pennsylvania is described by Stiemke (343). Chemical precipitation is recommended, consisting of high-test hypochlorite at the rate of 0.2 lb. available chlorine (in 70 per cent HTH) plus 3 to 5 lb. filter alum per 1,000 gal. B.O.D. reduction of 96 per cent is claimed. Cost is estimated at 12.5¢ per hog unit. Studies were made at a plant killing only 6 to 20 hogs units per day.

An aeration plus sand filter plant for rendering wastes from processing 20 tons of meat scraps per day has been described by Uhlmann (364). The flow averaged from 125,000 to 165,000 g.p.d. The primary settling tank had a detention period of 2 hr. There were two aeration tanks with a total capacity of 100,000 gal., and two sand filters, each 25 by 53 ft. by 3 ft. deep. Air consumption was about 2.5 cu. ft. per gal. B.O.D. was around 650 p.p.m., reduced to 15 p.p.m. in final settler effluent, and further to 3.0 p.p.m. in the filter effluent.

A new $4,000,000 plant is being built for the South Side district of Oklahoma City. The description, by Benham (58), shows that the contributory population is 175,000 and the present flow 18 to 20 m.g.d., containing packinghouse wastes from the Armour and Wilson plants plus 11 small slaughterhouses. Two detritors, 4 primary clarifiers giving 2-hr. detention for a flow of 50 m.g.d., and 4 primary high-rate filters (each 166 ft. in diameter and 6 ft. deep), provide the preliminary treatment. The filters are loaded at 4,330 lb. per acre-ft. per day, delivering an effluent containing only 60 p.p.m. of B.O.D. Secondary filters (8 at 186-ft. diameter) will be loaded at 416 lb. per acre-ft. Digesters have a capacity of 1,600,000 cu. ft., or 7.5 cu. ft. per capita on the present actual population, or 3.6 cu. ft. on an equivalent basis. Wynmore (395) describes a trickling filter plant for a small meat packing plant.

Fermentation Wastes

A series of six papers by Rudolfs and Trubnick (310) (311) (312) (313) (314) gives a very complete record of the study of the treatment of compressed yeast wastes at the Old Bridge, N. J., plant of Anheuser-Busch. The earlier work, started in the laboratory, was followed by treatment in a laboratory pilot plant, which led to larger pilot-plant digestion experiments which determined loadings, not to exceed 0.10 lb. per cu. ft. per day to give maximum efficiency. Hydrogen sulfide in the gas averaged 2.0 per cent at this loading. Higher loadings gave lower removals and more H_2S in the gas. In other tests a trickling filter was used, giving 50 per cent B.O.D. reduction and permitting loadings up to 11,000 to 12,000 lb. per acre-ft. with some reduction in percentage removals, but a breakdown at higher rates. Recirculation, surprisingly, showed no improvement over straight application. Sludge formation is discussed and the over-all suggested treatment. The digesters should be loaded at the rate of 0.1 lb. B.O.D. per cu. ft. per day and the trickling filters at 5,000 lb. per acre-ft. per

day. B.O.D. reduction is expected to average 90 per cent. Loadings of the filter varying from 0.2 to 8.0 lb. B.O.D. per cu. yd. per day (323 to 12,900 lb. per acre-ft.) gave filter efficiencies decreasing from 58 to 40 per cent.

In practical application, if 100,000 g.p.d. of waste having 5,000 p.p.m. B.O.D. are to be treated by digestion, and 95 per cent B.O.D. reduction is to be obtained, a two-stage digester loaded at 0.095 lb. per cu. ft. per day would be necessary. The digesters would total 44,000 cu. ft., with a detention period of 79 hr. Trickling filters at 5,000 lb. per acre-ft. per day could increase over-all B.O.D. reduction to 98 per cent.

Characteristics and treatment of rum wastes were discussed by Sawyer and Anderson (316). The wastes had a B.O.D. of 25,000 to 50,000 p.p.m., suspended solids of 2,230 to 5,975 p.p.m., total solids of 5.33 to 7.78 per cent, ammonia nitrogen of 1 to 36.5 p.p.m., and pH of 3.7 to 4.7. The waste was treated by a two-stage laboratory biofilter after admixture with sewage (1 per cent rum waste). Application rate of the mixture was 15.3 m.g.a.d., with a recirculation ratio of 3 to 1. B.O.D. application was at the rate of 2,590 lb. per acre-ft. per day. Over-all B.O.D. removals averaged 95.9 per cent with an average influent B.O.D. of 485 p.p.m. Small amounts of ammonia nitrogen were present in the effluent, indicating that sufficient nitrogen existed in the mixture being treated.

An investigation of disposal of grape stillage by irrigation was made for the Wine Institute in California (43). It is concluded that an intermittent irrigation system, when properly constructed and operated, will prevent offensive odors and mosquitoes. The irrigation area is planted with green crops. Another report made by the same organization (42) deals with the disposal of grape stillage by evaporation. The following products can be recovered by evaporation: glycerine food acidulent, tartrates, pomace feed, fertilizer, and grape seed oil. A 50 per cent reduction in the liquid volume of stillage, still changes, more condenser water, more pumping and steam capacity, and heavy investment in new equipment are required for most wineries to utilize this system. Legault, *et al.* (232) reported the results of investigations with the use of anion exchangers for the recovery of tartrates from grape wastes. Common salt solution serves as the regenerating agent. The concentration of tartrate is increased 15 to 18 times over that in the original slop. The useful life of the exchange material is 500 cycles giving a recovery of 1,800 to 2,000 lb. of tartaric acid per cu. ft. Clarification of the slop would reduce the fouling of the beds and loss of materials by attrition. Excellent clarification with efficient tartrate recovery would yield an effluent with reduced B.O.D.

A process for penicillin and streptomycin wastes described by Heukelekian (166) involves developing seed material by aerating a suspension of soil or sewage in the wastes. The residue is settled and a portion of the supernatant liquor used to seed a fresh batch of raw waste. For wastes of B.O.D. up to 1,000 p.p.m., efficiency may reach 90 per cent. With strong wastes (up to 4,000 p.p.m. B.O.D.), reduction was 70 to 80 per cent. Subsequent biological processes can be used to obtain greater reduction.

Penicillin and streptomycin wastes have also been studied by Heukelekian (167). Sedimentation and chemical treatment are of little value. Anaerobic digestion is feasible, giving 80 per cent B.O.D. reduction with a daily volumetric dose of 5 per cent. Aeration may reduce the B.O.D. 90 per cent. A fine-grain sand filter will bring the B.O.D. down to 35 to 40 p.p.m. Streptomycin wastes are treated even more easily.

Chemical and Pharmaceutical Wastes

The disposal of wastes from the Calco Chemical Company at Bound Brook, N. J., was discussed by King, *et al.* (207). River analyses were presented, indicating depletion to 0.6 p.p.m. dissolved oxygen in July, 1947, when the river flow was only 114 m.g.d., but such low flows occur rarely, usually in the fall. The wastes are largely organic chemicals (intermediates) and dyes containing largely acid, sulfur compounds, and aniline derivatives. Sulfides and thiosulfates are salvaged and there are a few additional recovery processes, but the major problem is neutralization of acid and abatement of the color due to dyes, which is accomplished in large lagoons by addition of waste lime sludge and mixing colored wastes, with discharge of an effluent of pH about 4.0 and a uniform brownish liquid to the river, with a B.O.D. not exceeding 125 p.p.m. A foam seine across the river holds back any occasional foam discharge and sludge is dredged out of the lagoons.

Hess (164) discussed the disposal of wastes from manufacture of intermediate organic chemicals and dyes, describing the organization of a waste disposal unit, the logical investigation and abatement of wastes, methods of removal or treatment of wastes, organization of the Manufacturing Chemists' Association for study and alleviation of waste production, and relation of wastes to stream disposal standards. This paper outlines in a comprehensive way the position of the organic chemical industry in relation to the problem of waste disposal.

The Hercules Powder Company at Mansfield, Mass., manufactures various synthetic resins, with wastes totalling 2,000 lb. B.O.D. per 24 hr., discharged to such a small stream (Rumford River) that only 30 lb. per day was permissible. Therefore, all feasible methods of reducing the B.O.D. were studied and reported by Dickerson (103). Most of the oxygen demand was in solution; chemical treatment was ineffective, as the organic matter was largely rosin and resin oils, formaldehyde, pentaerythritol, sodium formate, and organic acids. A high-rate filter was found suitable, after neutralization and dilution. The filter was of terra cotta pipe 10 in. in diameter and 6 ft. deep. Diluted formaldehyde was applied at 500 p.p.m., diluted to 60 p.p.m. by pond water. The over-all reduction was 82 per cent. Later, formaldehyde up to 1,500 p.p.m. was eliminated and recirculation continued at 40 to 1 rate. Over-all reduction was 90 per cent. These results were followed by feeding a synthetic mixture similar to plant wastes, with equally good results. It was concluded that biological oxidation was possible, and a full-scale plant was designed. It is now in operation.

In the neutralization of sulfuric acid by upflow passage through a bed containing small particles of limestone, the Water Pollution Research (377) reported that the limiting concentration of sulfuric acid, above which inactivation of the bed occurred due to the deposition of calcium sulfate, increased as the temperature of the waste decreased. Ferrous and ferric sulfates could not be removed in the upward flow limestone bed, but they did not interfere with the neutralization of free acid.

Paper Wastes

White Water.—The literature on pulp and papermill wastes contained several papers on white water clarification. Most of these concerned the application of flotation equipment to this process. Easton (109) and Hutchinson (188) review the application of the Sveen-Pedersen saveall to board and papermills, respectively. The first paper includes flow sheets, suggesting various methods of integrating the unit into board mill white water systems or comments on chemical control and operation. The second article details the

integration of the unit in papermills, stressing mechanical changes and improvements necessary to obtain optimum results. Operating data are presented for a number of different types of production for properly installed and operated machines. These figures indicate that in most cases effluents having suspended solids concentrations below 25 p.p.m. could be consistently obtained under ideal conditions. Advantages of the high consistency of the recovered fiber are pointed out.

Another type of flotation clarifier known as the Savalla is described by Niberger and Bodette (276). Although many chemicals have been employed to induce flotation, it is pointed out that in papermill practice aluminum salts appear the best. Operating results presented for a newsprint mill covering 11 test periods indicate an average efficiency of 91 per cent fiber recovery. An arrangement of a two-machine tissue mill for water reuse and fiber recovery employing a Sveen-Pedersen saveall is described by Simpson (326). Detailed analytical data are given for both cylinder and Fordrinier machine losses.

The decision of the city of Baltimore, Md., to establish a reservoir on the Patapsco River created the problem of treatment of felt paper wastes by Congoleum Nairn Inc. The results of studies for treatment of such wastes are reported by Irwin and French (193). The materials used in the production of felt paper are rags, wood pulp, and waste paper. None of the processes requires chemical cook. The water system has been closed, so that only 1,200 gal. of fresh water is used per ton of paper. The recirculated water is passed through savealls. The discharge to the stream amounts to 125,000 g.p.d. The waste has a pH of 5.2 to 5.7, B.O.D. of 1,410 to 3,160 p.p.m., and total solids of 3,300 to 9,200 p.p.m. The wastes are discharged into a lagoon with a theoretical detention period of 7 or 14 days, where the B.O.D. is reduced to about 2,000 p.p.m. To meet the requirements of 50 p.p.m. B.O.D. before discharge into the stream, the following methods of treatment were investigated: lagooning, sedimentation, chemical treatment, dilution, and biochemical purification. Lagooning was found to be insufficient for disposal without further treatment. Sedimentation and alum treatment gave no B.O.D. reduction. Dilution with fresh water was not practical. The waste could be treated on filters. The optimum volumetric rate of application was 1.7 m.g.a.d. A B.O.D. of less than 50 p.p.m. could be obtained in the effluent with an applied B.O.D. of 200 p.p.m.

Sulfite.—An excellent illustrated description of the magnesium sulfite pulping process, now under full-scale development, is presented by Callahan (80). This process is of interest in that stream pollution is virtually eliminated, because the waste liquor is burned and magnesia and sulfur dioxide are recovered. A paper by Folger, *et al.* (129) covering spray drying coefficients, and one by Kobe and McCormack (216) dealing with pulping liquor viscosities, are important from the standpoint of the development of waste liquor recovery processes.

Stevenson and Bollen (342) report on extensive field experiments designed to determine the feasibility of using dilute sulfite waste liquor in irrigation waters. Rates of application ranging from 10 to 120 tons per acre were applied annually to areas on which potatoes, corn, beans, and cabbage were grown. The crops were rotated throughout the 5-year experimental period. The heaviest rate applied (120 tons per acre) was depressing on the growth of some crops, but it was concluded that 60 tons, or 0.5 acre-in., can be used annually in dilution with irrigation water without harmful effect on the soil.

Experiments involving the use of calcium-lignosulfonate prepared from sulfite waste liquor in portland cement were reported by Scripture (322). Addition of small quantities imparted beneficial effects to cement, both in the plastic state and after hardening. The quantities of liquor presently so employed are small, but the author foresees a possible large usage. Tyler (363) gives the composition of sulfite waste liquor and discusses the various methods of disposal of this waste.

As a result of some preliminary work conducted at Oregon State College under the sponsorship of the National Council for Stream Improvement (273) a process has been developed for heat hydrolysis of sulfite liquor. The process consists of placing the liquor in a closed system and heating it at various temperatures and pressures. A B.O.D. reduction of 60 to 70 per cent could be obtained at 197 p.s.i. At this pressure, the residual material was a black liquid containing some solid residue which could not be readily separated from the liquid. At pressures of 300 to 410 p.s.i., the carbonaceous material agglomerated and separated relatively easily, giving an over-all B.O.D. reduction of 70 to 90 per cent.

Digestion.—Four articles appeared bearing on high-rate anaerobic digestion of pulping wastes. Gehm and Morgan (135) described the design of a digestion system employing continuous agitation in the digester, and external liquor-sludge separation with sludge returned to the digester feed. Laboratory digestion experiments on strawboard waste, on which this design was based, are reported by Bloodgood and Kinneman (271), together with other studies on this waste, including lagooning and a classified analysis of raw straw in relation to effluent losses. Research conducted on the influence of sulfite on methane fermentation by Noordam-Goedewagen, *et al.* (278) were of interest in that the use of sulfites in pulping straw and other raw materials is expanding. Their conclusions were that fermentation of alkaline and alkaline-earth acetates was initially inhibited by sodium sulfite concentrations as low as 0.003 per cent. It was observed, however, that after lag periods, recovery took place due to reduction of the sulfite to sulfide. Buswell, Pagano, and Sollo (79) studied the effect of sodium sulfate and chloride concentration on the methane fermentation of fatty acid salts identical to those present in pulping wastes. Sodium sulfate or chloride concentrations as high as 1.0 per cent were tolerated by mesophylic digestion, but cultures failed at 1.5 per cent sodium chloride concentrations. Sodium sulfate concentrations as low as 0.4 per cent inhibited the fermentation of glucose in the thermophylic range.

De-inking.—Operation of a pilot plant for reducing the suspended solids and dissolved B.O.D. of de-inking waste was the subject of an article by Morgan (265). With a bio-aeration system employing an excess of air, B.O.D. reductions averaging 68 per cent could be obtained with a 6-hr. aeration period with waste having an initial B.O.D. consistently in excess of 500 p.p.m. and a pH value of 9.5. Sodium nitrate was employed for adjusting the carbon-nitrogen ratio. The presence of considerable filler in the aeration tank feed produced a secondary sludge that settled and compacted very rapidly, allowing extremely quick return. Trickling filter experiments run concurrently with this study indicated the aeration process considerably more efficient. Filter leaf tests demonstrated that primary sludge could be dewatered on a vacuum filter at rates between 7.7 to 10.2 lb. of dry solids per sq. ft. per hr. at cake moistures averaging 66 per cent. Secondary sludge, coagulated with lime, could be dewatered at rates of from 14 to 24 lb. per sq. ft. per hr. Coagulated mixtures of primary and secondary sludges yielded

filter rates of about 9 lb. per sq. ft. per hr.

Sludge Dewatering.—Pilot plant experiments on the sedimentation and sludge dewatering of integrated mill waste were reported by Erspamer and Rice (118). In addition to a complete description of the plant, operating results are summarized in this paper. Settleable solids removal averaged 97 per cent, and total suspended solids reduction 82 per cent, when a 1-hr. detention period was employed in the settling tank. Extension of this period to as much as 4 hr. did not produce substantially greater suspended solids removals; nor did preflocculation. Accompanying B.O.D. reductions amounted to about 15 per cent. Pilot vacuum filter tests indicated that filtration rates of 1.2 to 5.2 lb. per sq. ft. per hr. were obtainable with the sludge, depending on the initial consistencies, which ran from 2.0 to 5.0 per cent solids. With the addition of lime on black ash, filter loadings could be increased 45 per cent. Cake moistures of 71 to 78 per cent were recorded; the filtrate was similar in character to the raw waste.

Semi-Chemical Wastes.—Research on the character and treatment of semi-chemical pulping wastes was reported by Vilbrandt, *et al.* (269) (272). Detailed chemical and sanitary analyses of these wastes revealed that the major pollutional characteristics were B.O.D., color, and suspended matter. The B.O.D. is due mainly to fatty acid salts and hemi-cellulose, the color to lignins and tannins, and the suspended matter to wood fiber debris. High degrees of color removal accompanied B.O.D. reductions in the order of 30 per cent, but produced hydrous sludges for which exhaustive experimentation failed to produce dewatering methods. Considerable exploratory work on various chemical and electro-chemical methods of treatment did not yield promise. Preliminary aerobic and anaerobic treatment tests revealed the fact that high B.O.D. reductions can be so obtained and this work is being continued.

Van Horn (270) presents studies on the toxicity of kraft mill waste to insect larvae important as fish food. Data reveal that insect larvae are much more resistant to potentially toxic substances than either fish or the microfauna, hence cannot be affected by kraft mill discharge in normal dilutions.

Cannery Wastes

Treatment.—Logan (237) reports on the operation of a Vacuator installed to overcome excessive scum formation experienced on a clarifier during the 5-month period when fruit and vegetable cannery waste amounting to 50 per cent of the domestic sewage flow was received. The Vacuator, serving as the sole primary unit ahead of a roughing filter which allowed the clarifier to be used for secondary settling, removed 40 per cent of the suspended solids of mixed sewage and cannery waste and from 55 to 60 per cent of the settleable solids by weight. Higher solids removal would have been obtained had not the cannery waste been pre-screened through a 40-mesh screen. Scum formation was completely controlled.

A full-scale cannery treatment plant and its operation is described by Dickinson (104). The plant consists of primary settling tanks, trickling filters, secondary settling, and orifices to provide a return of 5 parts of final effluent to 1 part of raw waste. The B.O.D. of the mixture applied to the filters ranged from 84 to 191 p.p.m. and that of the final effluent from 11 to 21 p.p.m., based on monthly averages during 1948. The rate of application was approximately 3.5 gal. (Imp.) per cu. yd. per hr. The filters are 6 ft. deep, graded from bottom to top as follows: 2 ft. of 2-in., 2 ft. of 1½-in., and 1.5 ft. of 2-in. limestone, with a top dressing of 6 in. of large clinkers. Sludge is dried on under-drained drying beds.

Conditions at this plant, located in England, differ in many respects with the average American cannery where canning is seasonal, the daily hours of operation are longer, and the volume and B.O.D. of the waste are much higher.

McNary (252) presented a brief review of the waste disposal methods in use at Florida citrus canning plants and announced a pilot plant anaerobic digestion investigation scheduled for the 1949–50 canning season under the sponsorship of the Florida Citrus Commission. Sanborn (315) gave a general presentation of the subject of cannery wastes. Factory process waters from washing of products, blanching, spillage, and cleaning of equipment and floors, constitute the most difficult wastes. Treatment methods consisting of one or more of the following are discussed: screening, chemical precipitation, cannery operated biological filtration, lagoons, absorption fields, and discharge to a municipal sewage works. Treatment or disposal methods for (a) water derived from the heat sterilization and cooling of sealed containers, (b) solid wastes, (c) domestic plant sewage, and (d) special wastes with high B.O.D. but small volume are briefly described. A table is given showing the volume, B.O.D., and suspended solids of wastes incident to the canning of a number of different products.

Utilization.—Investigations on the utilization of cannery wastes received considerable attention during 1949. Burdick, Anderson, and Duncan (77) gave flow diagrams and operating data on the commercial application of submerged combustion to the production of citrus peel molasses. Citrus peel liquor obtained during dewatering in the course of citrus feed manufacture is heated in the first of two submerged combustion units, followed by gravity separation of insoluble calcium salts and partial concentration in the second unit, prior to final concentration in a double-effect evaporator. The submerged combustion treatments overcame a serious evaporator scaling problem and effectively pasteurized the liquor so that losses due to fermentation prior to evaporator concentration were eliminated. The process is an innovation in citrus molasses manufacture.

Recovery.—Miller (256) discussed citrus meal and citrus molasses, recovered from citrus cannery waste solids, as components in mixed cattle feeds. Analyses and suggested formulas are given. It was concluded that "citrus pulp and molasses are the most economical per unit of total digestible nutrients of any feed ingredient produced."

A description of the processes used in pilot plant production of feed yeast from citrus press liquor and cannery pear wastes, with particular emphasis on the latter, was given by Ramage and Thompson (299). Pear waste juice with added mineral nutrients is aerobically fermented with *Torulopsis utilis* at a pH of 4.5 and at a temperature of 94° F., with the sugar concentration maintained at 0.1 to 0.2 per cent in the propagator. Yeast is separated in a centrifugal concentrator and the resulting cream dried in a steam-heated rotary drum. Yields of yeast as high as 57 per cent of the weight of sugar fed have been obtained. The process, except for juice extraction, is continuous, and after initial adjustments is operated under automatic instrument control. It is estimated that when a practical continuous juice press becomes available the waste disposal costs in canning pears will be more than offset by the value of feed yeast obtained. Chong and Cruess (85) experimentally treated pureed pear wastes with a pectic enzyme, which after filtration yielded about 75 per cent by weight of juice containing about 13 per cent of soluble solids, mostly sugar.

After decolorization the syrup may be used in canning pears. The value of the syrup thus recovered is greater than the cost of preparation.

Beohner and Mindler (59) presented the general principles of ion exchange and application to waste treatment. Examples of ion exchange processes are recovery of organic acids, pectin from grapefruit cannery wastes, and sugar syrups from fruit cannery wastes. Felton (124) presented an outline of the process and chemical data on ion exchangers for recovering sugar syrup and citric acid from pineapple cannery wastes, as conducted in the Hawaiian Pineapple Company's ion exchange plant.

Adams (5) reported on studies for the recovery of industrial alcohol, indicating that a rapid, continuous fermentation of pear, apple, and cherry cannery wastes is practicable. A tentative design for a mobile alcohol recovery unit mounted on railroad box cars is given. Because the primary objective is the solution of a waste problem, conversion of the fermentation residues to stock feed is proposed. Whether the process will be profitable or not will depend on several factors, including the value of the by-product feed and ability to supplement the operation of the unit on other carbohydrate wastes, such as cull potatoes.

A brief description of the background, organization, and objectives of a joint government-industry research project which led to the operation of a large pilot plant for the treatment of solid wastes from fruit and vegetable canning plants was given by Clevenger (87). End products of the pilot plant studies have been (a) a dried pumice suitable for stock feed containing all the fiber in the waste and some of the sugar and other soluble material, and (b) a concentrated syrup fraction that can be fermented to produce industrial products or disposed of as stock feed molasses.

Dairy Wastes

Eldridge (114) discussed the use of return sludge type of treatment of milk waste at Belle Center, Ohio. Consistently excellent effluent has been obtained under widely variable conditions. The excess sludge volume is relatively large, and a thickener is used to reduce the volume. The digestion appeared to be very complete with 9-day detention at 90° F. No digested sludge had to be withdrawn during 1 yr. of operation.

Helmboldt (161) discussed dairy waste saving and also pointed out the importance of keeping relatively large amounts of caustic from bottle washers out of a milk waste treatment plant of the return sludge type. The difficulty was overcome by pumping the caustic to a storage tank whenever the bottle-washing machine had to be cleaned, and returning the caustic for re-use after cleaning the machine.

Trebler and Harding (360) have also reported excellent results with return sludge (activated sludge) type of treatment for milk waste.

Treatment of milk washings by addition of coagulants, sedimentation, and biological filtration is discussed by Southgate (332). At one plant, milk washings are treated with 300 p.p.m. of alumino-ferric and soda ash to raise the pH to 7.0, mixed, and then allowed to settle. The supernatant is treated by biological filter 11 ft. deep at the rate of 340 g.p.d. per cu. yd. The chemical treatment removed 75 per cent of the 286 p.p.m. B.O.D. of the raw waste, and the final effluent had a B.O.D. of 14 p.p.m. In another plant, on milk washings the 690-p.p.m. B.O.D. of the raw waste was reduced to 320 p.p.m. by the application of 170 p.p.m. alumino-ferric, and then further reduced to 6 p.p.m. by filtration through a 5-ft. deep bed at the rate of 60 g.p.d. per cu. yd.

Tannery Wastes

Experience at Ballston Spa, N. Y. (295), has indicated that tannery wastes can be handled at the municipal plant to greater advantage if received daily and not stored by the industry. Reuning (300) presents a diagram of a modern chemical precipitation plant for handling the waste from a tannery. The most difficult task in treating these wastes is the disposal of the sludge, best done by lagooning, drying on beds, or dewatering in centrifuges. The solid materials from the latter processes are recommended to be used as soil builders. A Swiss patent was granted (16) on a process where the alkaline and acid wastes are mixed, filtered, treated with Fe (powder or turnings) to complete the removal of sulfides, and filtered again. The iron sulfide is periodically added to the mixed wastes. The process removes about 55 per cent of the total solids, 82 per cent of the organic matter, practically 100 per cent of the sulfides, and lowers the permanganate number about 72 per cent. Vrijburg (374) reports on a group of sole-leather tanneries in North Brabant. These plants produce 1 to 2 cu. m. of settled waste water per cowhide. The waste has a B.O.D. of 712 p.p.m. Analyses of the waste water from the various operations are given and suggestions made for improving the wastes discharged.

Textile Wastes

A report of the North Carolina State Stream Sanitation and Conservation Commission (81) shows data compiled from the study of the wastes from 16 textile mills. The report covers a great many types of wastes and gives sufficient information to describe each definitely. Buswell, *et al.* (79) state that the use of glucose in rayon spinning baths leads to a waste with a B.O.D. as high as 5,000 p.p.m. and that it is not readily treated by the usual methods because of the high salt concentration. It was found that sodium sulfate in concentrations of 4,000 p.p.m. or more makes the methane fermentation of glucose at 55° C. impossible. Acetic acid, however, can readily be fermented in the presence of as much as 10,000 p.p.m. of either sodium chloride or sodium sulfate at 37° C. Zack (396) describes the waste treatment plant used by a mill processing cotton, rayon, nylon, and other synthetic fibers from thread woven into fabrics that are dyed black or bleached white. The waste liquors resulting are from bleaching, scouring, rinsing, dyeing, sizing, and finishing processes. Because of the variation in the character of the waste, chemical precipitation was selected as the method for treatment. The chemically treated waste, after sedimentation, was ponded for about 20 days. The B.O.D. of the raw waste is 697 p.p.m., of the clarified effluent 254 p.p.m., of the pond effluent 53 p.p.m. Operating costs are between $90 and $100 per day. The plant was designed to handle 75,000 g.p.d.

Wool Scouring Wastes

Singleton (327) working with the wool scouring wastes from a woolen mill at Lebanon, Tenn., found that with anaerobic digestion the volatile matter could be reduced 65 per cent and the grease 90 per cent. He states that anaerobic fermentation presents a possible practicable solution to the problem of the treatment of wool scouring wastes. McCarthy (247) says that the use of carbon dioxide and calcium chloride, in combination, offers a reasonably simple, rapid, and inexpensive method of treating wool scouring wastes. The carbon dioxide reduces significantly the amount of coagulant necessary, and its use is essential for best results. The process can be used with sedimentation or flotation. Coburn (88) compares centrifuging, chlorine treatment, acid cracking, calcium hypochloride processing, and calcium

chloride processing as methods of treating wool scouring wastes. He states that where ample dilution is available, treatment of wool scouring wastes by any of the methods described will be satisfactory. No economical method of treatment has been developed which will produce an effluent comparable to those obtained by the conventional sewage treatment processes.

By-Product Coke Wastes

Bundy and Jordan (76) outlined essential steps in making a by-product coke plant waste water survey. It was found that 77 per cent of the phenol entering the river came from the final cooler. It was necessary to increase the efficiency of phenol recovery from 83 per cent to 95 per cent or better to meet West Virginia requirements. Installation of a final cooler water recirculation system will eliminate phenol from this source and permit the plant to hold its phenol discharge below the allowable minimum. This paper contains considerable useful data. The Institute of Sewage Purification (27) recommends that only "spent" ammoniacal liquor be discharged to sewers; that the discharge be constant, or in proportion to the sewage flow; and that gas tar be completely absent from the liquor. No more than 0.5 per cent of spent, or 0.25 per cent of crude, liquor should be sent to a sewage treatment plant. Ettinger and Ruchhoft (119) state that microbiological action is the principal cause of removal of phenol and cresols in surface waters. Rates of removal are governed by metabolic factors. A chart is presented to guide estimation of low-temperature persistence of such compounds in waters of different types. Data (17) are given on the volume and concentration of wastes from coke plants in the Ohio Valley.

Petroleum Refining Wastes

Albright (9) described a method for treating spent caustic solution which involves recirculating the liquor in a plate column countercurrent to a stream of flue gas. Sulfur gases stripped from the liquor are burned, and phenol is recovered from a settling tank by skimming. The first commercial plant to convert the hydrogen sulfide in refinery gases to sulfuric acid was described by Albright (8). Hydrogen sulfide is stripped from the gas by scrubbing with diethanol amine. It is steam-distilled and burned with a deficiency of oxygen, whereby elemental sulfur is separated. The unreacted gas is converted to sulfuric acid catalytically. Over-all economics are said to be sound.

King (206) reported that the oil separator to handle waste waters from the Sohio and Pure Oil refineries at Toledo, Ohio, is operating satisfactorily. The separator, which differs from the conventional A. P. I. design, is removing 80 to 85 per cent more oil than the old facilities. Atlantic Refining Co. has developed (30) an automatic waste water sampler that holds the samples at 42° F., found to be the optimum temperature for keeping biological changes to a minimum. Ullrich (365) discusses improved results following establishment of a separate stream pollution control department at the Esso Baton Rouge plant. The various steps taken by the new group to reduce pollution are outlined in some detail.

Schindler (318) reported on the operation of a plant-scale experimental process for treating spills of sulfonated alkyl aromatics. Waste water is adjusted to pH 5 to break emulsion, then lime is added to pH 8; if decolorization and settling are poor in this step, pH is raised to 10, and ferrous sulfate is added. The treated waste is allowed to settle and the supernatant is discharged at a controlled rate. The plant has been treating 850,000 gal. per month for 2 years. Faulconer, *et al.* (122) described a plant which conditions refinery effluent water for reuse. The

main waste water stream is softened and clarified with lime, soda ash, and ferric or aluminum sulfate in a reactivator sludge recirculation unit. The effluent passes through an anthracite pressure filter to a surge tank, where a phosphate stabilizer and sulfuric acid are added to maintain the proper pH. Treatment costs average 4.3¢ per 1,000 gal. A cation-exchange material produced from acid sludge was patented by Higgins (171), and Haycock patented (160) the application of sludge acid to alkaline soil to improve its quality.

Oil Well Brines

Jessen (197) reviewed current practice in subsurface injection of brines. Open-type treatment systems require an investment in equipment of about $50,000; closed-type systems, which can be used for volumes under 5,000 bbl. per day, cost about $10,000. In both cases, $25,000 to $30,000 must be added for the cost of the injection well. This type of disposal rarely costs more than 1.5¢ per bbl., and many plants using partial chemical treatment have total costs of 0.2¢ to 0.5¢ per bbl. of water injected. It has been reported (29) that plastic tubing is in successful use for subsurface injection of brines. Zufeldt (397) states that about 2 bbl. of brine is produced per barrel of oil in the East Texas field. Injection of treated brines below the oil-water contact has almost stopped the decline in bottom hole pressure; has solved an acute pollution problem; and has increased the estimated ultimate recovery from the Woodbine reservoir by 600,000,000 bbl. Brine is treated by skimming, aeration, coagulation, filtration, and chlorination. A chlorine-resistant bacterium, thought to be *Vibrio thermodesulfuricans*, reduces sulfates causing formation of ferrous sulfide, which plugs injection sands. Permanganate has been found to be a more powerful oxidizing agent in these waters than chlorine or chlorates; 1.1 lb. of potassium permanganate per 1,000 bbl. of brine will inhibit bacterial growth. Cost of this treatment is $2.40 to $2.75 per 10,000 bbl., as compared with a cost of $3.00 to $3.25 for chlorine, lime, and alum. Hatfield (159) discussed experience in Kansas, where brines are pumped to a settling pit for oil-skimming, then pumped to injection wells. These may be depleted wells, dry holes, or new drilling. It is important to exclude air as much as possible. The investment cost per system serving a group of wells ranges from $1,000 to $3,000; operating costs vary with the injection pressure and the amount of water a well will take. Sawyer, *et al.* (317) describe the recovery of iodine from brines as practiced by Dow Chemical Co. in California. For determining oil in brines, Kirschman (208) favors extraction with hexane. With samples containing less than 25 p.p.m. oil, 95 per cent is recovered in two extractions, 99 per cent in three. Duplicate samples differed by less than 1 p.p.m. Naphthenic acids are extracted with the oil and must be removed by saponification. Oil is defined as the non-saponifiable, hexane-soluble fraction; this material most closely represents the oil content that contributes to the formation of oil films and deposits. Bond and Savoy (68) have patented a soap for breaking brine-in-oil emulsions.

Oil Wastes

Bradt (72) recommends filtering steam boiler condensate, instead of blowing off steam, to keep oil out of boilers, thereby eliminating a minor pollution problem. Haseltine (157) describes the sources of, and methods for treating, soluble-oil emulsions. His laboratory experimentation on 5 commercial products gave results that differed from those of Eldridge and Purdy (116) in some respects. He found that a number of electrolytes will break emulsions partially or completely, and, even though these oils are

highly alkaline, addition of more alkali improves breaking, coagulation, and clarification. Calcium chloride is a good emulsion breaker, but in some instances so much may be required that the effluent will be toxic to fish. Where pickle liquor is available it may be used with lime, in a single-stage process, to treat emulsions. He notes that where the oil content is high, free oil and/or flocculated material may float instead of settling; increasing the coagulant dosage will reduce this tendency.

Treatment of wastes arising from a sheet and plate rolling mill containing soluble oils is described by McMorris (251). The wastes are first treated by gravity flotation. The removal of the emulsified fraction was studied by two-stage chemical treatment. The emulsion was cracked by treatment with alum, followed by sedimentation and alkali treatment with lime to the point of floc formation, followed by secondary sedimentation. Effective removal of oils was obtained. A plant was designed and built incorporating these features. Alum is added at 7 g. per gal. and lime at 10 g. per gal.

The addition of carbons and carbon coated sand to the surface of water containing oil is reported to remove the oil from the surface and submerge it to the bottom by Hofmann (178).

Pickling Wastes

Hoak and Sindlinger (175) introduced a new pickle liquor neutralization technique that involves controlled aeration of the liquor after treatment with an alkaline material (experimental data are given for magnesia, and for high-calcium and dolomitic limes). This procedure yields a slurry that settles completely in less than ½ hr. to the smallest attainable volume. Filtration rates in excess of 400 lb. of wet cake per sq. ft. per hr. were recorded for high-calcium lime slurries; the wet cake contained 60 per cent dry solids. Wragge (393) presented a survey of methods in general use throughout the world for dealing with pickle liquor. Neutralization and crystallization techniques are discussed, including operating costs and materials of construction for some processes. A ternary equilibrium diagram ($H_2O/FeSO_4/H_2SO_4$) was included to facilitate theoretical and practical calculations for acid recovery processes. He concludes that the pickle liquor problem is incapable of a simple solution, but that its magnitude could be reduced by improved plant housekeeping. Lewis (235) found that greatly improved sludge filterability could be attained by treating pickle liquor with a 250 to 400 per cent excess of dry quicklime. This treatment produced a granular sludge that could be dewatered readily in a basket-type centrifuge. This method would be suitable for a plant producing up to 3,000 g.p.d. where lagoon space was not available. As the volume to be treated increases, the cost of excess lime outweighs the advantages of the method. Bliss (64) outlined available and potential processes for handling liquors from the copper and brass industry as follows: precipitation, ion exchange, extraction, electrochemical, electrolytic, and crystallization. Plots of variation of constituents *vs.* time were included, as well as a discussion of cost estimating and pilot plant operation. Boehner and Mindler (67) reported that copper and chromium in copper alloy pickling wash waters can be concentrated 25-fold in a carbonaceous hydrogen exchanger, which is regenerated with sulfuric acid. Farrell (121) compared grit-blasting with pickling for cleaning steel and concluded that, although blast cleaning may eliminate some of the disadvantages of pickling, its use will be limited by production and operating conditions; each case must be decided on its own merits by applying tests that follow conditions in a given plant. Hicks (170) found the efficiency of sewage sludge conditioning agents to be, in

order: ferric chloride, chlorinated copperas, ferric sulfate, aluminum sulfate, and chrome alum. He states that it would be theoretically possible to condition all the sludge in England and Scotland with iron salts from the pickle liquor produced there. Chlorinated copperas is too costly in comparison with the efficiency of ferric chloride. He proposed operating electrolytic tanks in conjunction with pickling, and calculated that ferric chloride could be made by this method for $36 per ton, as compared with $70 by direct chlorination. Groen (151) reported the results of plant-scale tests at Dearborn, Mich., on the use of pickle liquor and lime to condition raw sewage sludge for vacuum filtration and incineration. Pickle liquor filter cakes averaged 6.2 per cent less moisture, required 8.1 per cent less lime, and gave 18 per cent longer filter-cloth life than ferric chloride. Complete data on plant runs were included.

Kraicker (221) discusses the Wheatland Tube Co.'s plant for converting the pickling liquor waste to ferric hydrates, zinc sulfate, and zinc chloride. The plant cost $500,000 and it is claimed that the operation is profitable. The raw materials are pickle liquor, chlorine, and zinc waste, a by-product of galvanizing steel pipe.

The Water Pollution Research Board (377) states that the sludge formed from precipitation of iron in pickling liquor by the addition of alkali or lime could not be dewatered readily by filtration. Oxidation by aeration effected little improvement in the properties of the sludge. The addition of limestone and aeration resulted in slow separation of a dense granular precipitate, which filtered readily. Upon addition of sodium carbonate to pH 6.0, and aeration, a fairly granular precipitate of ferric hydroxide was formed. Addition of chlorine and stirring with limestone also produced a dense granular sludge.

Plating Wastes

Gurnham (152) outlined the objectives of the American Electroplaters Society, Research Project No. 10, established to investigate and develop methods for treating plating wastes. Dodge and Reams (105) presented a comprehensive critical review of the literature on plating wastes, citing 700 references. This work is available from the American Electroplaters Society as Research Report No. 14. Gurnham, *et al.* (153) outlined records to be kept in making a survey of plating-room wastes. Kelch and Graham (202) described an electrometric method for continuous control of the reduction of hexavalent chromium by ferrous sulfate. The system operates through linkage of a platinum-calomel and glass electrode for control of reductant and acid, respectively, which actuate solution-feed mechanisms. A diagram of the system is given; it is reported to operate successfully in practice. Bleiweis (63) reviewed methods for disposing of plating wastes. He cited specific values for some processes, and included a description of the Kaiser-Frazer disposal plant at Willow Run. Priester (297) described an installation for treating a combination of degreasing and plating wastes which involves a combination of acid-cracking for the oils and hypochlorite treatment of cyanide rinse waters. Before-and-after values are given. Kominek (218) discussed the general principles of plating waste treatment, citing operating costs and techniques, plus useful control values. Harrold (155) does not approve of treating cyanide wastes with acid and discharging the fumes to a stack. He recommends (a) lagooning; (b) treatment with sulfur compounds to form thiocyanates before lagooning; (c) oxidation to carbonate; (d) oxidation with waste oxidants and discharge to sewer; and (e) incineration. He claims that the plating waste problem is quite simple, involving only

judicious scheduling for combining acid and alkaline wastes to yield a neutral product. Unwin (367) described the New Departure waste treatment plant built by General Motors as an integral part of a new manufacturing plant. The plant produces a consistently clear effluent from a mixture of cutting oils, pickling, and plating wastes. Treatment is in two stages, with a standard circular clarifier for separation of oils, and a cyclator for precipitation of heavy metals after reduction of chromium with ferrous sulfate. Williams (385) described the continuous alkali-chlorine system installed by National Carbon to treat both weak and strong cyanide solutions. Gipson (138) provided a flowsheet, construction details, operating figures, and a process equipment table for the alkali-chlorine cyanide disposal plant installed by Western Electric. Oyler (285) discussed the disposal of waste cyanides by electrolytic oxidation. Conditions of operation are the opposite of those for proper plating. They embody high temperature, insoluble electrodes, and vigorous agitation, which results in accelerated decomposition of cyanide to carbonates and ammonia. The process requires a minimum of attention; recovered metal may be used for plating-tank anodes; and solution strength is not critical. Cyanide is destroyed at an average rate of 1 oz. per gal. per day; but the higher the concentration, the higher the rate. Sperry and Caldwell (333) also describe the electrolytic destruction of cyanides and point out that the effluent may contain 5,000 p.p.m. cyanates, which should be destroyed by treating with sulfuric acid until the pH, after boiling, remains just below 7. Cost data are given. Smith (331) patented a process for detoxifying cyanide waste liquors, comprising adjusting the pH of the liquor to between 5 and 8, insuring the presence of ammonium ion in excess of its cyanide equivalent, and oxidizing below 60° C. to ammonia and carbon dioxide. Pettett and Thomas (292) studied the effect of cyanides on the operation of trickling filters. They found that 2 p.p.m. interfered with nitrification and 4 p.p.m. resulted in an increase of B.O.D. in the effluent. At concentrations up to 10 p.p.m., 98 to 100 per cent of the cyanide was destroyed in the filter. Sudden application of 30 p.p.m. inhibited nitrification and led to an effluent of extremely poor quality; on continued application of sewage containing this concentration the filter gradually recovered and produced an effluent of satisfactory quality, free from cyanide.

Water Softening Wastes

The disposal of wastes from both lime-soda and zeolite water softening plants is now a recognized industrial waste problem. Black (62) reports on the extent and types of problems involved in the disposal and recovery of lime-soda softening plant sludges. In addition to the usual methods of disposal, such as lagooning and dilution into water courses, 4 other possible methods are described, some of which are so new that their practicability has not been established. The suggested methods are: (a) utilization of sludges as a precipitant for primary sewage treatment; (b) dewatering, drying, and pulverizing for use by agriculture and industry; (c) dewatering and recalcining in small stationary kilns for small softening plants; and (d) dewatering and recalcining in large rotary kilns for large water treatment plants.

The disposal of zeolite softening brines can cause serious difficulties if insufficient dilution is afforded by the sewage system or receiving stream. Some instances of brine disposal troubles are described, and several methods of disposal (such as evaporation ponds, controlled dilution, and disposal wells) are discussed. The conclusion reached by the committee is

that controlled dilution offered the best method of brine disposal in most instances.

Tank Car Washings

An unusual industrial waste from tank car cleaning operations is described by Gutzeit (154). Because many types of products are shipped in tank cars, the cleaning wastes are similar in composition to those from the combined chemical, coal tar, petroleum and food industries. The problem of treatment is further complicated because waste flows are extremely variable. Oil wastes, which predominate, are settled to remove sludge and free floating oil. After pH adjustment to 4.5, powdered coal is added to adsorb remaining oils and phenols and the waste is mixed in turbo-mixers. Coal and adsorbed oil is removed by flotation and thickened for use as fuel, the effluent being either reused, ponded, or discharged to the stream. Another installation, treating similar wastes, separates caustic tank car wastes for disposal by solar evaporation; other wastes are treated with ferrous sulfate and lime and the effluent lagooned for disposal by seepage and evaporation. Effluent qualities from the described systems are not given.

Cider Wastes

The treatment of wastes from cider manufacture is reported by Jones (199). Experimental work was conducted with a 2 per cent solution of cider, either alone or mixed with an equal volume of sewage, on a single trickling filter or a single recirculated filter and application rates from 20 to 100 g.p.d. per cu. yd. with a B.O.D. of the cider-sewage mixture varying from 650 to 1,060 p.p.m. At the rate of 40 g.p.d. per cu. yd. the effluent had a B.O.D. of 6 to 7 p.p.m. by either system. At a 60-gal. rate the effluent from the recirculated filter was superior, but with a B.O.D. of 1,060 p.p.m. a 60-gal. rate gave effluent of 116 p.p.m. B.O.D.

Cider has an organic carbon content of 32,500 p.p.m. and only 10 p.p.m. of total nitrogen. Accordingly, the treatment of diluted cider without sewage or additional nitrogen gave poor B.O.D. reductions, whereas additions of inorganic nutrients gave improved results.

Coffee Wastes

Brandon (73) reports that coffee processing wastes treated with standard coagulants gave B.O.D. reductions of less than 50 per cent and produced voluminous sludges. Anaerobic fermentation reduced the B.O.D. from 1,760 to 800 p.p.m. in 4 days and to 270 p.p.m. in 12 days. A unique coffee processing and waste treatment pilot plant is described in which the effluent from a recirculated filter was reused to process the coffee cherries. Recirculated filters reduced the B.O.D. of the wastes more than 95 per cent and settled effluents when reused gave no significant impairment in the quality of the processed coffee.

Sisal Wastes

The Water Pollution Research Board (377) reported that the reuse of waste waters from processing sisal fibers, after screening and biological filtration, would solve the pollution problem. The waste contains large quantities of dissolved organic matter derived from the non-fibrous portion of the sisal leaf, which is removed from the decorticating machine by water. Difficulties in treating the waste water would be greatly reduced if a method of dry decortication is used with only the fiber being washed. Fiber washings after dry decortication had a B.O.D. of 180 p.p.m., whereas wet decortication washings had 1,540 p.p.m. B.O.D.

Grain Washing Wastes

Mixed wheat washing waters from two mills had B.O.D. values of 270 and

815 p.p.m., suspended solids of 450 and 2,580 p.p.m., and volumes of 784 and 211 (Imp.) gal. per ton of wheat, respectively (377). Barley steep waters for the production of malt had the following B.O.D. values; first steep liquor, undressed barley, 4,470 p.p.m.; third steep liquor, undressed barley, 770 p.p.m.; and first steep liquor, dressed barley, 720 p.p.m.

Beet Sugar Wastes

In an article on beet sugar manufacturing problems, Allen, *et al.* (12) show some of the manufacturing problems connected with sugar extraction in the diffuser batteries. Chemical changes, organic acid production, and sugar losses are brought about by the fermentation of the sugar by thermophylic bacteria. It is intimated that the undesirable conditions are intensified by the reuse of water in the batteries, and some suggestions are made for bacteria control.

Water Pollution

Abatement and Control

Water pollution legislation was adopted in a number of states during 1949. California (19) passed an Act which provided for a 13-man board with 9 regional boards. New York and Vermont (381) each passed Acts which enabled the state to join the New England Interstate Water Pollution Control Commission. Michigan (40) broadened its law and increased penalty fines. Instead of the 5-man Stream Control Commission, Michigan now has a 7-man Water Resources Commission, authority being increased to cover ground waters, flood control, and beach erosion. Bloodgood (65) concurs in the trend towards broad powers for state control boards.

Fleming and Ewing (127) outlined the National Water Pollution Program as authorized by Public Law 845, 80th Congress. The Public Health Service with its Water Pollution Control Advisory Board, the Water Pollution Control Division in Washington, the Environmental Health Center in Cincinnati, and 14 river basin offices, is administering the financial and technical assistance to states. State responsibility is recognized. No grants or loans were appropriated. Hart (156) reviewed the Water Pollution Control Act from the standpoint of petroleum refineries and indicated that the industry should examine its position and plan now for necessary treatment plants.

Bloodgood (66) stated "in general, the court evidence gives backing to the law," in reference to stream pollution, but indicates a need for a compilation of all available court evidence that shows the condition of streams declared to be polluted by the court. Murdock (268) indicated that water works legal departments must consider riparian rights, nuisance laws, and statutory laws dealing with stream pollution, regarding protection of water supplies from pollution.

Watson (378) describes the various types of interstate compacts, commissions, and committees for water pollution control as of September 1, 1948. There were four compacts operating with the concurrence of the federal government, one interstate agreement (Incodel), and three additional informal pollution control instruments, involving 21 states and the District of Columbia. The Ohio River Compact (378) (18) has authority for the issuance of orders. It requires a minimum of 45 per cent suspended solids removal from domestic sewage and industries can probably be compelled to provide similar primary treatment.

The New England Interstate Water Pollution Control Compact, as described by Scott (320) and Weston (381), during 1949 increased its participating states of Massachusetts, Connecticut, and Rhode Island, by adding New York. This compact operates with enforcement by the individual states

where necessary, not by order of the compact. Streams are classified as A, B, C, or D on the basis of stream use. Many streams in Massachusetts (381) will require complete sewage treatment plants, including effluent chlorination, in order to be improved to Class C.

Allen (10) described the activities of the Interstate Commission on the Delaware River Basin (Incodel) as coordinating existing agencies of state and local governments in New York, New Jersey, Pennsylvania, and Delaware, with reference to stream pollution and conservation of the Delaware River and its tributaries. Philadelphia and Camden have under way construction programs totaling $75,000,000, and a program involving $35,000,000 of state and $20,000,000 of Federal funds is under way to clean up coal mining wastes on the Schuylkill River in Pennsylvania (26).

The Interstate Sanitation Commission (New York, New Jersey, and Connecticut) was described by Hess (165) as being concerned only with the coastal, estuarial, and tidal boundary waters. It has established definite chemical, bacteriological, and physical standards for these waters and can issue orders to meet requirements.

The first annual report of the Ohio Valley Water Sanitation Commission (280) has established standards of treatment for the special areas in the vicinity of Cincinnati, Pittsburgh, and Huntington-Ashland-Ironton. The Commission also undertook joint studies of oil pollution in the basin and a special study of the Wabash River. Based on lists of pollution offenders from the 8 states, notifications were issued to 1,159 municipalities and 1,422 industries.

LeBosquet (231) described the 1909 treaty between the United States and Canada, and the 1913 and 1946 surveys of the St. Clair River. The latter survey was a joint undertaking involving several federal, state, and provincial agencies. Final conclusions of the International Joint Commission have not yet been submitted to the governments of the two countries.

Pond (294) has pointed out the importance of proper conservation and use of water resources. He indicates the necessity for planning by all interests, the setting of standards for water uses, and the development of a realistic and effective program to conserve water. An editorial reports (21) that the sum of $850,000 has been allotted to the states, territories, and District of Columbia for grants to study water pollution resulting from industrial wastes. In addition, $150,000 was allotted to state and interstate agencies for special studies and $1,200,000 to the Public Health Service for operation, research, administration, and planning. Another editorial (23) indicates that 42 states have anti-pollution laws and that these vary greatly in the control powers granted.

Winget (389) (390), in discussing the relation of industry to stream sanitation, points out: (a) most industrial wastes, such as those from the pulp and paper industry, are not a health menace or bacterial pollution problem; (b) individual industrial waste treatment procedures and facilities have to be developed in the laboratory; and (c) industrial waste treatment cannot be financed by public funds, but must be paid for with operating funds.

Milligan (257) indicated that the Pennsylvania Sanitary Water Board requires a definite percentage reduction in B.O.D. as the criteria of treatment; 35 per cent for primary treatment and 85 per cent for complete treatment. The Board also plans to establish standards, in pounds of B.O.D. pollutant, for each of 16 types of industrial wastes. Editorial comments (22) (25) indicate that Pennsylvania has obtained cooperation from 47 collieries on the Schuylkill River, 114 of 136 on the Susquehanna River, and 6 on the Lehigh River in a drive to

eliminate anthracite pollution. The program on the Schuylkill will cost $35,000,000, has resulted in 99.9 per cent reduction in solids in the river, and should result in $15,000,000 of salable anthracite fines.

Kittrell (209) and Clark (86) described the stream sanitation program of the T.V.A., indicating that, although not directly concerned with water quality of the streams, the T.V.A. assists state agencies in surveys, planning, educational activities, and public relations. Fox (130) states that 5 industries on the Buffalo River have installed expensive plants for treatment of oil and acid wastes. These industries also agreed to buy Lake Erie water from the Buffalo Sewer Authority for cooling purposes and to discharge spent water into the Buffalo River to supplement low flow periods.

Sulfite waste liquors cause a large part of the total pollutional effect in the Androscoggin River as described by Chase (84). There is an apparent benefit in odor control by the addition of sodium nitrate to the river.

The Washington State Pollution Control Commission (20) (376) found dangerous contamination by sewage of all Puget Sound and Elliott Bay beaches, with 100 sewer outfalls discharging into the Sound.

Hoffert (176) and Kolasinki (217) point out the importance of effecting the removal of industrial wastes from streams, the latter particularly stressing means of handling waste sulfite liquor. Warrick (375) enumerated the principal industries causing pollution problems in Wisconsin as canneries, paper mills, and dairy establishments, and mentioned the progress in waste treatment in these industries.

Kittrell and Thomas (210) explain the legal aspects of the government's liability regarding damage by flooding to existing water supplies in connection with impoundments. T.V.A. was required to furnish a supply equal in quality to the previous supply to any community whose system was actually flooded. Beneficial effects of impoundage enumerated were: more nearly constant stream flows; reductions in coliform concentrations, turbidity, alum requirements, and chlorine demand; and reduced fluctuations in characteristics, such as hardness, alkalinity, pH, color, and manganese. Adverse effects of storage have been: color removal, density currents, structures in navigable channels, and tastes and odors.

Woodward and LeBosquet (392) also point out improvements and damages to water quality as a result of reservoir operation. Improvements may result due to: (a) increased dilution of wastes due to increased stream flow, (b) prevention of injurious minimum-flow conditions, and (c) reduction of temperature of streams used for cooling water. Damages may include: (a) contaminating upstream water supplies by impounding free-flowing tributaries to the reservoir, (b) possible heavy algal growths, and (c) great fluctuations in stream flow if the reservoir is operated for power generation. Benefits and damages may be estimated in monetary terms in most cases.

Biology and Bacteriology

Cohn (90) recommends that aquatic biologists and limnologists work with sanitary engineers and chemists to arrive at an adequate understanding of stream conditions and the effects of pollution.

Henderson (163) showed that although the lower Shenandoah River is relatively free of pollution by accepted physical, chemical, and bacteriological standards, it contains virtually no fish or other aquatic animals because of toxicants from industrial wastes. The Surber bottom sampler is a useful device to evaluate the impact of pollution on fish-food organisms, and consequently on fish.

The role of the algologist in safe-

guarding municipal and industrial water supplies was outlined by Taft (351). By predicting algal blooms, algicidal treatment can be initiated before serious difficulties arise.

Johnson (198) discussed the effect of hydrographic and chemical conditions of lakes on the biology of plankton populations and their vertical and lateral movements. The position and fluctuation of the heaviest concentrations of plankton should be considered in determining levels from which water for domestic use should be drawn.

Abbott (2) found that the rate of production of oxygen by the freely developing mixed cultures of very small algae in sewages containing trade wastes is proportional to the quantity already produced and inversely proportional to the time elapsed.

Moyle (267) reported that algicidal treatment of 4 Minnesota lakes resulted in an increase in fish production over 5 adjacent untreated lakes. Apart from an apparent increased tolerance of *Aphanizomenon* to the copper sulfate algicide, it appeared that ordinary algae control had little effect on plankton and aquatic seed plants. The toxic effect of copper accumulation in bottom muds is, however, still unknown.

Lackey (228) finds plankton blooms occurring at any time of the year when optimal light, temperature, pH, and food (especially inorganic nitrogen and phosphorous) occur. The still-inadequate algae control methods fail to completely prevent blooms, resulting in acute nuisance conditions. Furfural derived from the methyl-pentosan content of the phytoplankton of some waters was determined in some acidified water samples by Skopintsev (329). The furfural varied from a few to 100 p.p.b. in Russian river and lake waters, and up to 600 p.p.b. in swamp waters.

Allen, Blezard and Wheatland (11) found that cyanogen chloride and another unknown substance toxic to rainbow trout are formed when the cyanides and thiocyanates in gas liquor effluents are treated with chlorine doses smaller than that required to give a chlorine residual.

McKernan, *et al.* (248), after a thorough study, attributed the decline of the Olympia oyster industry in lower Puget Sound to sulfite waste liquor (S.W.L.) pollution. Oysters subjected for 575 days in 13.0 to 128.9 p.p.m. of S.W.L. were definitely harmed; tolerance lies between zero and 13.0 p.p.m. S.W.L. A modification of the Pearl-Benson test for S.W.L. was presented, which consisted in the application of photoelectric colorimetry, together with methods of minimizing the effect of the variable water color.

Van Horn (368) pointed out that efficient kraft pulping operations can prevent toxic concentrations of the sodium salts of resin acids and of the blowdown condensates from reaching streams.

Experiments testing the toxicity of DDT, benzene hexachloride, chlordane, and chlorinated phenol insecticides applied as various emulsions and solutions to various Alaskan salmonids, were reported by Cope, Gjullin and Strom (95). DDT in acetone and fuel-oil solution, chlordane in acetone and fuel oil, and toxaphene in acetone, were effective blackfly toxicants likely to be safe to fish and fish-food organisms.

Hoffman and Surber (177) found that aerial application of a DDT-oil spray of 1 lb. per acre in two Pennsylvania watersheds killed several fish species in ponds, lakes, and streams. Three days after spraying, 70 to 80 per cent of the stream insects, including fish-food organisms, were destroyed. Toxicity to amphibians was negligible, but mortality of water snakes was high.

Chang (82) discussed the possible dissemination of cysts of the dysentery amoeba in inadequate water supply systems. Ketchum, Carey, and Briggs (204) conclude that an organic, heat-

labile, antibiotic probably produced by marine bacteria rapidly reduces the number of coliform organisms in domestic sewage disposed into sea waters and estuaries. Further study of this antibiotic and adequate knowledge of principles governing the mixing of water masses are indicated in order to plan efficient marine sewer outfalls.

To produce and market oysters suitable for U. S. Public Health Service certificaton, the Virginia Health Department (372) regulates all phases of oyster culture, preparation, and distribution.

Wilson (388) observed that the microbiotic agents of self-purification in streams are found in the same gradients in sewage treatment plants. These organisms are divided functionally into binding, free-living, and scouring groups, the successions of which are affected by food supply and dissolved oxygen content. A DDT emulsion, equivalent to 1 p.p.m. of the total daily sewage flow, controls filter flies without the destruction of the biological film. Bartsch and Churchill (53) found no abrupt biological improvement in the North Fork of the Flambeau River near the artificial reaeration site, but improvement in the downstream recovery zone is accelerated. The sulfite pulp effluents have an immediate toxic effect on most organisms, and alter the biological picture for 20 stream miles. In downstream areas, the organisms increase and reach a population peak which is followed by a linear decrease as their biochemical activities change the degree and character of pollution.

Chemistry

In a symposium on the oxygen balance (266), Moses gave a general outline of the D.O. and B.O.D. tests as applied to streams; McQueen discussed sampling, sample preservation and handling, and the subsequent effect these steps have on the reliability of B.O.D. and D.O. data; Madison advocated the use of an oxygen consumed test in the evaluation of industrial wastes. Kononov (219) noted greater utilization of oxygen by dilutions of Moscow River water than was used by the undiluted river water and concluded that this effect was caused by the presence of a toxic substance in the river water. The study of such effects was recommended as a criterion useful in ascertaining the presence of toxic materials.

Ruchhoft and Ettinger (307) discussed factors bearing on the transportation or destruction of industrial wastes in surface waters, and the subsequent control or accentuation of tastes and odors, due to such materials, by various water treatment processes.

Besozzi and Vaughn (61) discussed the problem of producing a palatable drinking water at Whiting, Indiana. The raw water is polluted by both industrial wastes and domestic sewage. All available water treatments were tried. Activated carbon treatment was the only method which gave a satisfactory product. Relief from the pollution load due to the sewage is expected.

Stream Standards

There appears to be a marked trend toward stream zoning. Agar (6) cited the details of recent New York legislation, which requires stream zoning on the basis of the interests of the public after public hearing. Quality standards are to be fixed on the basis of zoning allocation. The West Virginia Water Commission (383) reported zoning action in the Potomac basin. Criteria for zoning are based on the use of the water for public supply, fish culture, or recreation. Weston (381) reports an agreement made in 1946 between the engineers of Massachusetts and Connecticut for classification of their interstate waters on the basis of stream usage. Weston further reports that no streams leave Massachusetts

in a nuisance condition, although such conditions do exist within the State boundaries.

The Maryland Water Pollution Control Commission has established sewage effluent standards (245). Industrial waste standards are based on the satisfactory ecology of the stream below the discharge. The Policy Committee recommends that standards be set up considering all factors and all parties involved. King, *et al.* (207) suggest that it would aid industrial control of pollution if a specific industry were allocated a reasonable amount of such stream resources as dissolved oxygen and acid neutralizing power on the basis of study of the specific streams involved. Hoak (174), discussing this paper, gave qualified approval.

Establishment of standards for discharge into the Cincinnati pool by the Ohio River Valley Sanitation Compact was reported (37). Substantially complete removal of settleable solids and 65 per cent reduction of B.O.D. are required.

Streeter (347) reported recent trends in proposed standards of stream sanitation and discussed trends in the further development of standards. Stevenson (341) discussed the evaluation of standards for bathing waters, fish culture, shellfish grounds, boating, and camping. Akerlindh (7) discussed factors concerned with the establishment of tolerances for short-time discharges of B.O.D. or bacteriological loads. Gorman (141) cited recommendations by Morgan for maximum tolerances of radioactive materials in water.

Oxygen Sag and Self-Purification

Thomas (353) presented a method for the application of the oxygen sag curve to stream data, employing nomographs. The sag curve formulation is modified by the introduction of a third constant, k_3, which takes cognizance of a variety of factors such as deposition or scouring of solids and nonparallel flow. Howland (184) pointed out that Thomas' sag method had much in common with a method of calculation previously presented by Howland. Thomas (354) agreed that Howland's method had a great deal of merit, but maintained that his formulation (353) was better adapted for application to streams of rapidly changing characteristics.

Streeter (346) presented a nomographic method for solving the oxygen sag equation. Velz (371) considered sludge accumulation, run-off, and stream velocity as factors affecting the oxygen sag. Gotaas (144) found that up to 25 per cent of sea water increased rates of biological oxidation. Further increases in the concentration of sea water resulted in decreased rates of oxidation. The sea water concentration did not affect the magnitude of the first-stage B.O.D.

Nothlich (279) pointed out factors affecting the oxygen balance of the Elbe River below Hamburg. The domestic sewage of Hamburg is given primary treatment. A dilution factor of 20 : 1 for waste given primary treatment is considered satisfactory. Oxygen absorption of 4 to 5 g. per sq. meter per day is considered a further criterion of satisfactory decomposition.

Kooijmans (220) discussed the pollution and self-purification of the River Vecht. This river is especially important because it eventually becomes a part of the water supply of the city of Amsterdam.

Ettinger and Ruchhoft (119) found that the aerobic destruction of phenol and cresols in natural waters is largely the result of biochemical attack. Factors controlling the rate of attack on such materials are discussed and curves are presented which permit estimate of the low-temperature persistence of phenolic materials. Kemp (203) presented a detailed report of damage done in the Potomac basin by pollution resulting from soil erosion.

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STATUS OF MUNICIPAL TREATMENT IN OHIO BASIN

Only 11 per cent of the cities over 5,000 population in the area encompassed by the Ohio River Valley Water Sanitation Commission are catalogued as "having taken no action" toward the installation of sewage treatment facilities. This was revealed at a recent meeting of the Commission, where reports from 311 municipalities were compiled from the sanitary engineering departments of the eight signatory states.

This record was cited by a Commission spokesman as encouraging evidence that the states are aggressively promoting pollution abatement measures in the basin. He said, however, that this did not mean that anyone could be complacent, as only 76 cities actually have proper treatment works; another 31 have plants, but they are inadequate. Faster progress was urged on the part of the 144 communities now preparing plans for construction.

Elected to take office in July, 1950, as chairman of the Commission was Henry Ward, commissioner of conservation in Kentucky. Mr. Ward has been vice-chairman of the Commission.

Succeeding Mr. Ward as vice-chairman is Clarence W. Klassen, technical secretary of the Illinois Sanitary Water Board and chief engineer of the Illinois Department of Public Health. F. H. Waring, chief engineer of the Ohio Department of Health, was re-elected secretary. Robert K. Horton, sanitary engineer on the staff of the Commission, was elected to serve as treasurer.

The Commission received a preliminary report, by H. W. Streeter, on bacterial quality objectives to be sought in connection with water supply and bathing uses of streams in the basin, and approved a basin-wide sampling program designed to secure the picture of present water quality conditions.

Industrial Wastes

TREATMENT OF DISTILLERY WASTES *

By Alex B. Davidson

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The treatment of industrial wastes is becoming even more important as population and industry continue to grow, as evidenced in the past several years by the decided increase in legislation regarding stream pollution. One of the foremost examples of such is the Ohio River Valley Water Sanitation Compact, which became effective in June, 1948. As the majority of the nation's distilleries are in the Ohio Valley, it is apparent that treatment and disposition of their wastes can be very important in this area. The Commonwealth of Kentucky alone, which produces the major portion of the country's Bourbon whiskey, has some 60 distilleries, most of which are congregated in the central or Blue Grass area, and which have a population equivalent of 7,800,000. The present population of Kentucky is 2,800,000, all contributing to the drainage area covered by the Ohio Valley Compact, which includes a total population of 20,000,000. It is apparent that if most distilleries did not utilize some method of waste treatment or recovery there would be a serious load on the streams of the state from the distillery industry alone.

The Distillery Process

The product of distilleries is quite well known. However, its method of manufacture may not be quite as familiar. As shown in Figure 1, the first step in the process is the grinding or milling of grains to form meal. Various types of whiskies use different raw materials, but for Bourbon whiskey the main ingredients are corn, rye, and barley malt, the usual amount of corn being about 75 per cent. After the corn is ground it is dropped into the cooker with approximately 20 gal. of water (per bushel) to form a mash. This material is then cooked for a period of from 15 min. to 1 hr., depending on whether the cooker is an open atmospheric type or a closed pressure cooker. After the corn mash is cooked it is cooled by vacuum and the rye is added. The malt is added immediately after, which converts the starches in the mash to sugar.

The mash is then cooled still further and pumped to the fermenters, where yeast and "back slop" are added as a prelude to fermentation. (The "back slop," which is previously distilled "beer," is added as yeast nutrient and as a measure of pH control.) The mash is allowed to ferment for 3 to 4 days until all of the sugar has been converted to alcohol. This fermented mash, now known as "beer," is dropped into a large tank or pit known as the "beer well," where it is ready to be distilled. The still is a tall hollow cylinder equipped with numerous perforated plates and heated by steam at the bottom. The beer enters near the top of the still and as it works its way downward against the

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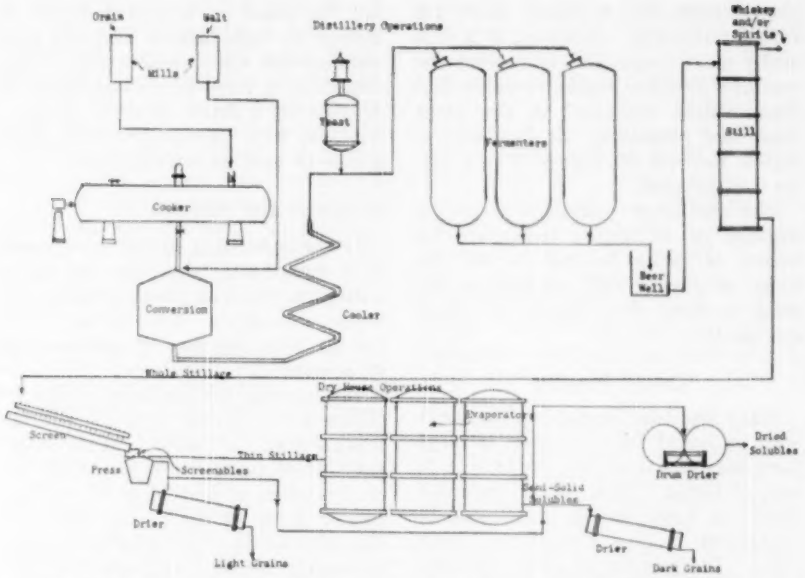

FIGURE 1.—Simplified flow diagram for Bourbon whiskey distillery and grain recovery plant.

rising steam vapors the alcohol is stripped from it leaving the still at the top in the form of vapor where it is condensed as a raw form of whiskey or spirits. The de-alcoholized beer, which emerges from the bottom of the still, constitutes the waste that must be recovered or disposed of in some manner. This material is known as "spent mash," "slop," "stillage," etc.

Spent Mash

The characteristics and analysis of spent mash depend on many variables in distillery practice. The strength of the beer fed to the still may be between 33 and 45 gal. per bushel of grain mashed, depending on the particular formula used, which of course will vary the solids and B.O.D. content of the spent mash considerably. The type of whiskey and the variation of raw materials will also change these properties of spent mash. In general, the B.O.D. of this material will be between 20,000 and 50,000 p.p.m. and the solids content will vary from 5.5 to 11.5 per cent. It is definitely on the acid side (pH 3.6 to 4.6) and is very corrosive to equipment. The waste also contains a certain amount of copper, as copper equipment and lines are used extensively in distilleries to combat corrosion. Many methods of disposing of spent mash have been discussed in the literature (1) (2) (3) and several different methods are in common use today in the industry. It is obvious from the high solids and B.O.D. content of the material that it could not be handled very successfully by present methods of sewage treatment (such as trickling filters, activated sludge, or anaerobic digestion) as a sole means of treatment, as even 95 per cent reduction of the B.O.D. still gives an effluent containing 2,000 p.p.m. B.O.D., which in most cases would be too strong to discharge. Past and present work indicates that the material might be handled fairly successfully by means of digestion as a

pretreatment and trickling filters for a final treatment. However, it is generally more economical to recover the available proteins, yeasts, vitamins, and other values contained in the spent mash and practically all distillers resort to methods of disposal which utilize this material.

The two most prevalent forms of disposal or utilization today are by means of cattle feeding in the wet form, or drying and evaporating the mash to form dried feeds for cattle and poultry.

Cattle Feeding

Many small distilleries feed the spent mash in liquid form to cattle in large pens near the distillery, or haul it to nearby farms. This method does not involve a large capital investment in equipment as does a modern drying plant. The number of cattle required is usually one head per bushel of grain mashed. Cattle pens are generally arranged so that the drainage of manure and urine from the cattle is collected in large ponds, which are cleaned periodically with the dredgings being used for fertilizer. This system has its drawbacks in the nature of odors and flies, and also the danger of the pond leaking or washing out a bank so that the strong waste will flow into a stream. However, if considerable land is available, not too near populated areas, and drainage conditions are such that the ponds can be protected, this method of disposal can be quite successful.

Drying

Most of the larger distilleries dispose of their spent mash by screening, drying, and evaporation, with the consequent recovery of dried grains for sale as cattle and poultry feed.

A simplified flow sheet of the dryhouse operation is shown in Figure 1. Briefly, the spent mash is passed through several types of screens and presses so that the screenable material can be dried in a rotary dryer to emerge as light grains and the thin unscreenable spent mash can be evaporated to a form of syrup, which is dryable on a drum dryer or in combination with previously dried light grains in another rotary dryer.

Screening and Pressing

In the processing of the spent mash it is economical to reduce the water content as much as possible before the drying operations. This is the reason for the large number of screens seen at present day distilleries. The material entering the dryhouse generally passes over several sets of gravity screens first. A portion of the spent mash which passes through the first of these screens is sent back to the fermenter room as the "back slop" to the fermenters. The gravity screens are merely inclined troughs with a false bottom of perforated plate or wire mesh. As the spent mash flows over the screen a considerable quantity of the thin watery material passes through to be collected in a "thin slop" tank and the heavier screenable portion passes on over the end of the screen.

The screenables from the gravity screens are then fed to a more efficient mechanical screen, several types of which are in use today. One, known as the drag screen, is very similar to the gravity screen, except that wooden paddles or blades are automatically dragged down or up the screen, squeezing and scraping more of the thin liquid from the waste material. Vibrating and gyrating screens are also extensively used. They are nothing more than a box with a screen or perforated bottom and as the box vibrates or gyrates the thin material is shaken out of the heavier mash. The screenables from this operation generally contain about 83 per cent water.

These screenables are next pressed or squeezed to reduce further the water content. The old-style roll press accomplishes this by squeezing the

screenables between two sets of rolls as they pass through on a perforated metal belt. The press most widely used at present consists of two perforated discs set at an angle to form a V. The screenables are dropped into the slowly rotating discs and as they pass on through the nearly closed end of the V, much of the water is squeezed out. The material from the presses is known as "press cake" and contains from 65 to 70 per cent moisture. This material is now ready to be dried.

Drying and Evaporation

The heavy pressed grain from the presses (the press cake) next passes into rotary steam-tube dryers, which consist of long horizontal cylinders lined with steam tubes. The cylinders are inclined very slightly so that as they slowly rotate, the press cake, which is fed into the upper end, gradually travels down the dryer, the rotating action causing it to contact continually hot steam tubes and gradually become dry. When it emerges from the dryers the dried grain usually contains about 8 per cent moisture and is ready to be packed for shipment as stock feed.

All the liquid (thin slop) removed from the various screening and pressing operations is collected in a tank and treated by means of evaporators. This material contains from 2.5 to 5.5 per cent solids, most of which are dissolved. The evaporators reduce the water content to approximately 70 per cent so that the thin spent mash reaches the consistency of syrup, which can then be dried in either of two ways to give two different end products. It may be fed to a drum dryer and dried by itself to give a premium product known as dried solubles. A drum dryer consists of two large, steel, steam-heated drums turning toward each other. The syrup falling between the drums is dried on the surface in the form of a sheet, which is scraped off by a knife arrangement. If drum dryers are not available, the syrup may be added to previously dried grains and passed through the rotary dryers to deliver a product known as dark grains.

The dryers and the evaporators are the heart of the dryhouse system, the whole theory and sequence of operations being built around them. The main purpose of the dryhouse is to remove moisture from its raw material (spent mash) as economically as possible. Because screening and pressing is purely a mechanical action, and also is the cheapest operation, it explains the large number of screens and the great attention given to new types of presses.

Dryhouse processing cost can be measured somewhat by pounds of steam used, the various types of drying and evaporating equipment being far different in their steam economies. The multiple-effect evaporators in general use are the most economical, removing approximately 2.25 lb. of water for every pound of heating steam supplied; in the rotary dryers 1 lb. of steam will remove only 0.85 lb. of water; and in the drum dryers, which are the least efficient of all, 1 lb. of steam will remove 0.65 lb. of water. This is the reason for attempting to remove as much moisture as possible in the screening and pressing operations so that there will be less water for the rotary dryers to remove. Also, because the evaporators remove water much more economically than either drum dryers or rotary dryers, it explains the numerous types of evaporators on the market, and the constant attempts to obtain a syrup of high solids content.

Source and Nature of Remaining Wastes

A modern, efficient dryhouse will remove better than 98 per cent of the pollutional material of the spent mash, which in most cases is sufficient to remove adequately any possibility of stream pollution. However, where the receiving stream has a small flow this

TABLE I.—Distillery and Dryhouse Wastes to Disposal Plant

(Typical 3000-Bu. Distillery with Dryhouse)

Type of Waste	Amount (g.p.d.)	Solids (p.p.m.)		B.O.D.		pH	Temp. (° F.)
		Total	Susp.	(p.p.m.)	(lb.)		
Evaporator condensate	45,000	130	12	600	225	3.9	125
Washes	21,000	1,050	400	1,000	176	6.0	70
Cooling tower overflow	24,000	1,100	200	550	110	8.0	115
Doubler	3,000	240	40	1,000	26	5.0	170
Domestic sewage	7,000	830	300	200	14	6.8	70
Total	100,000	610	160	670	551	5.0	110

remaining waste may be of sufficient strength to endanger it. The quantities and pollutional characteristics of these wastes are shown in Table I for a typical 3,000-bu. distillery making Bourbon whiskey and equipped with a complete dryhouse. It will be noted that domestic sewage constitutes a relatively small amount of the waste and is only of sanitary significance.

Wastes from the doubler are small in quantity, but relatively strong. The doubler is generally nothing more than a large steam-heated kettle, in which the first distillation from the beer still is redistilled or "doubled" to remove various impurities. After the day's distillation is finished the doubler "tailings" (the hot liquid in the doubler containing the removed impurities) are dumped.

Plant and equipment washes contribute considerably to the total waste, as shown in Table I. The quantity of wash water is rather hard to estimate, as it depends a good deal on the technique employed in the individual plants. This is one item that can possibly be decreased by careful operation and instructions. Many spills can be swept up dry, or shoveled up, instead of just washing them down the drain, thus eliminating a good deal of organic material. When washed down the plant sewer, 15 lb. of dried grains are equivalent to the sewage of 100 people.

Condensate from the multiple-effect evaporators and overflow from the cooling tower (if one is used) are the most important wastes as regards quantity and strength. It will be noted that evaporator condensate constitutes about 45 per cent of the total waste load by volume and strength, and together with the cooling tower overflow is equal to approximately 70 per cent of the total waste load. As the combination of condensate and cooling tower overflow is such an important waste, it will be discussed further.

A typical flow sheet of evaporators and cooling tower is as shown in Figure 2. A cooling tower may or may not be necessary, depending on the availability of water. Many plants fortunate enough to be situated on a large stream or with a plentiful well water supply require no reuse of water by circulating it through cooling towers, spray ponds, or other cooling device. As a cooling tower requires much less area, it is used often when insufficient land is available.

Evaporators are actually nothing more than closed boiling kettles that economize on steam consumption by vacuum operation and vapor heating. Low-pressure exhaust steam of 10-lb. pressure is used in the first-effect heating chest, inside the evaporator body. These heating chests are simply closed sections with numerous vertical tubes running through them so that there can be adequate circulation between the bottom and top of the evaporator body. As the steam condenses in the

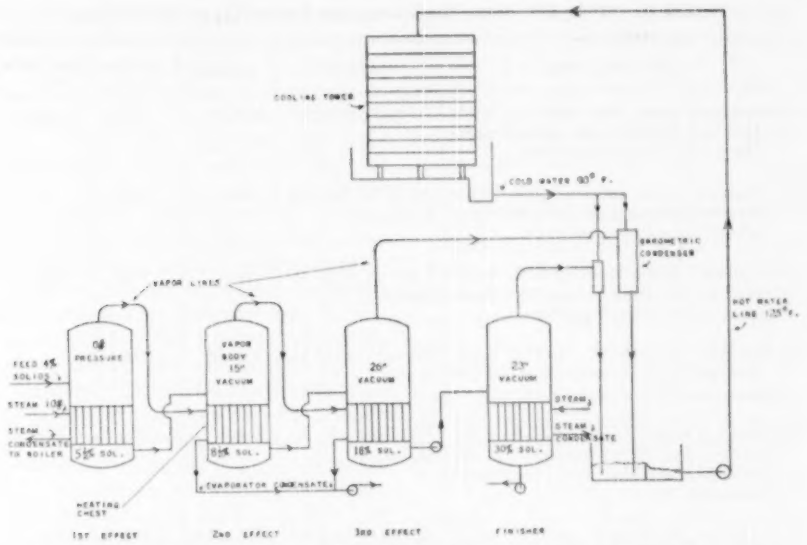

FIGURE 2.—Typical flow sheet of multiple-effect evaporators with cooling tower.

first-effect chest it gives up its heat, and the condensate, which does not come into contact with the spent mash because of the closed chest, is returned to the boiler for make-up. The spent mash feed generally enters the top of the evaporator body. As it passes through the hot tubes it is heated to boiling, giving off vapors. The vapors from this first effect are passed into the heating chest of the second effect, and the vapors from the second effect are passed to the heating chest of the third effect. These vapors condense in the two heating chests, and being under vacuum must be pumped out. This is the evaporator condensate, which contributes so much of the waste load (Table I). The vapors from the third effect are condensed in the barometric condenser by coming in contact with cold water. As the cold water condenses the vapors and falls down the long tailpipe (at least 32 ft. long) it causes a vacuum on the evaporator bodies, thus enabling a lower boiling temperature, with a consequent saving of heat. A vacuum of 26 in., which gives a boiling temperature of approximately 125° F. in the third effect, can be easily maintained by a good barometric condenser.

In the third effect the slop has been evaporated to approximately 18 per cent solids. This material is rather viscous, but can be concentrated still further. In this case, it is passed to a finishing pan, which is actually the same as the other evaporator bodies except that it is a self-contained unit having its own steam supply and a separate smaller barometric condenser. This finishing pan is generally maintained at a slightly lower vacuum to produce a higher temperature, as by the time the material reaches a 30 per cent solids concentration it is very viscous and becomes increasingly so at lower temperatures. This syrup must also be pumped out (to a syrup tank), because the evaporator body is under vacuum. The vapors condensed in the barometric condensers are the same as the vapors condensed in the heating chests of the second and third effects, but of course they are diluted

TABLE II.—Strength of Waste Condensate from Various Types of Evaporators

Type of Evaporators	Operation	Controls	B.O.D. (p.p.m.)	Total Solids (p.p.m.)
A. Standard short tube vertical, triple effect and finishing pan, natural circulation, basket type separators.	At max. capacity.	Auto.	675	133
B. Standard short tube vertical, triple effect and finishing pan, natural circulation, basket type separators.	At ¾ to full capacity.	Auto.	570	—
C. Standard short tube vertical, triple effect and finishing pan, natural circulation, basket type separators.	From ½ to ¾ capacity.	Auto.	510	147
D. Standard short tube vertical, triple effect and finishing pan, natural circulation, basket type separators.	From ½ to full capacity.	Partial	800	—
E. Standard vertical, quadruple effect and finishing pan, forced circulation in 4th effect and finishing pan, centrifugal separators.	From ½ to ¾ capacity.	Auto.	650	112
F. Standard short tube vertical, triple effect and finishing pan, natural circulation, baffle type separators.	From ¾ to full capacity.	Manual	1,580	270
G. Standard short tube vertical, triple effect and finishing pan, natural circulation, baffle type separators.	From ¾ to full capacity.	Manual	1,510	350
H. Vertical long tube, outside calandria, triple effect and finishing pan, natural circulation.	From ¾ to full capacity.	Semi-auto.	3,210	—
I. Same as H after larger vapor bodies and basket type separators installed.	From ¾ to full capacity.	Auto.	520	—

with a considerable quantity of water and where a "once-through" system is used (no cooling tower or no recirculation of cooling water) the B.O.D. of the condenser water will be approximately 40 p.p.m. However, where this water is reclaimed by use of a cooling tower its strength constantly increases as additional vapors are condensed. The acid vapors also lower the pH of the water and alkali must be added to protect the equipment against corrosion. Of course, the B.O.D. of the water will vary, depending on the operation of the tower; that is, whether there is a constant blowdown from the tower, and how often the tower is cleaned. Cooling towers and chilling systems also may be used in other distillery operations to conserve water. With complete reuse of cooling water throughout a distillery and dryhouse it is possible to operate with minimum water requirements of 40 g.p.d. per bushel; where no recirculation systems are used approximately 700 g.p.d. per bushel may be necessary.

The evaporator flow cycle described might be taken as a typical distillery setup, although many different types of evaporators are used. A comparison of various different types is given in Table II. It can be seen that a good set of evaporators will deliver a condensate of approximately 600 p.p.m. B.O.D., although this can vary con-

siderably, depending on the operation. Table II illustrates that evaporators with automatic controls, in general, are more satisfactory than manually operated sets. The effect of good evaporator design and automatic controls can be seen by comparing results H and I in Table II. In H it will be seen that the condensate has a very high B.O.D. (3,210 p.p.m.), but after modification by installing larger vapor bodies and better separators, together with automatic controls, the B.O.D. was lowered to 520 p.p.m., or approximately an 80 per cent reduction.

In most distilleries it is necessary to clean the evaporators and the cooker once or twice a week. This is generally done by boiling out the equipment with some type of alkali. Naturally, this clean-up water has a very high pH and considerable alkalinity. In fact, these characteristics are so high that the waste has a toxic effect. If the distillery is equipped with a biological waste disposal plant the material will completely upset the plant. However, it is not too difficult to handle and can be reused. The boiling caustic can be collected in a hopper-bottom tank and the sludge allowed to settle so that it can be blown off to the disposal system, the supernatant liquid then being made back up to strength with more alkali and reused.

Treatment of Remaining Wastes

There is little in the literature on the treatment of these remaining wastes, although apparently all methods have been tried. The wastes are rather easily oxidized and are definitely amenable to treatment on trickling filters. Although the activated sludge process should handle this material rather easily, experimental work has shown that it is not as satisfactory as a high-rate trickling filter, presumably because of the high content of copper in the raw waste. Evaporator condensate by itself has been observed to contain from 6 to 25 p.p.m. copper. In the activated sludge method this copper seems to concentrate in the sludge until it reaches a point where it has a toxic effect.

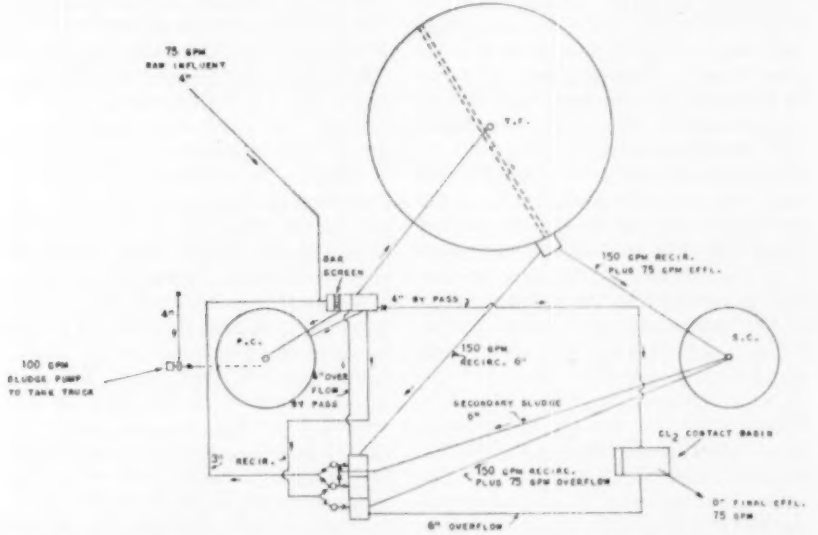

FIGURE 3.—Flow diagram for waste disposal plant at 3,000-bu. distillery with dryhouse.

FIGURE 4.—Typical distillery waste disposal plant.

The copper content seems to have no effect on the operation of trickling filters and a single high-rate unit will give average B.O.D. reductions of 93 per cent. A typical flow sheet of a distillery waste disposal plant is shown in Figure 3. In this particular design, recirculation is through both primary and secondary clarifiers, the high recirculation rate of 4 to 1 being necessary because of the high B.O.D. of the raw waste. As can be seen, the filtered effluent is split so that half of it goes through the secondary clarifier and half is returned to the primary. The settled recirculated filter effluent from the primary and the secondary then are mixed in the filter feed well, as shown, before going to the filter. Sludge from the primary and secondary clarifiers is digested or stored. In this particular case it is digested in the lower compartment of the primary clarifier, which is actually a combination clarifier and digester.

The filter equipment used is of standard sewage plant type with conventional loadings in the clarifiers. The filter, however, is slightly different because of the low-water loading of 8.0 m.g.a.d., this being for a 6-ft. deep filter with a B.O.D. loading of 0.75 lb. per cu. yd. Low-water loadings are considered conducive to ponding of the filter. To alleviate this condition, 3-in. to 4-in. size media are used. So far, in the operation of two plants of this type for several years, there has been no difficulty from ponding. However, one disadvantage of the low-water loading is that it apparently does not have enough washing action to completely control filter flies. The flies can be observed in the filter at any season, but they are not prevalent enough to be a nuisance. Their growth in the winter season is no doubt due to the high temperature of the waste, as even in cold weather the effluent from the filter may be as high as 85° F.

TABLE III.—Wastes Material Balance Sheet of a Typical 3,000-Bushel Distillery (Bourbon)

Effluent			B.O.D.		% Reduction	
Source	Type	Amount	(p.p.m.)	(lb./day)	Unit	Over-all
Distillery	Still slop	780,000 lb./day[1]	40,000	30,000	—	—
Dryhouse	Dried feeds	56,000 lb./day	—	—	—	—
Dryhouse	Waste waters[2]	100,000 g.p.d.	670	550	98.2	98.2
Disposal plant	Final	100,000 g.p.d.	45	38.5	93.0	99.9

[1] At 31 gal. per bu.
[2] Including distillery wash waters.

The actual B.O.D. loading on the filters (0.75 lb. per cu. yd.) seems to lie above the low-rate filter range and below the usual high-rate range. Recent experiments indicate that this loading could be increased somewhat, but not enough data are available actually to use a higher loading in a commercial size plant, such as shown in Figure 4.

Conclusions

Distillery waste can be effectively handled by modern methods so that there is little danger of pollutional possibilities. It has been shown that a modern dryhouse will effectively process the major portion of the organic material in spent mash so that it can be removed as dry feeds. Such a process will give a total B.O.D. reduction of 98.2 per cent as shown in Table III.

If inadequate stream flows are present, so that further treatment is necessary, this remaining waste can be treated by high-rate trickling filters with an average B.O.D. reduction of 93 per cent. The combined effects of the dryhouse treatment and the disposal plant treatment give an over-all B.O.D. reduction of 99.9 per cent.

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DISCUSSION

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This discussion offers some comments on the information presented in Mr. Davidson's paper and some actual operating experiences which prove that his suggestion of the use of digestion as pretreatment and trickling filters as final treatment do work in a plant, as well as in laboratory experiments.

Mr. Davidson has very clearly described the distillery processes and pointed out the magnitude of the pollution resulting from their operation in Kentucky, where the population equivalent of the waste is more than two and one-half times the total population of the state. A similar comparison between the total population equivalent of all such wastes in the United States and the total population would also be of interest. Similarly, how many bushels of corn, rye, and barley malt are used to produce the total gallonage of whiskies? The indicated resulting wastes from the processes are definitely too great a pollutional load to be carried by the streams without

creating a nuisance. Treatment of the wastes is a "must."

Realization of the necessity of stopping stream pollution was followed by a search for better and cheaper methods of waste treatment. It was not long before many industries discovered that they had been wasting thousands of dollars by dumping valuable waste materials into the streams. Researches were begun on methods for salvaging these waste materials and the development of markets for their use.

It has been the writer's privilege to supervise operation of the waste treatment plant of the National Yeast Corporation at Crystal Lake, Ill., since early in 1946. This plant employs digestion of the complete waste as pretreatment, and a trickling filter as final treatment—the process indicated as applicable to the treatment of concentrated distillery wastes. Its operation has had to produce results because of litigation involving it. The results obtained should be more convincing than any laboratory experimental work. That the combined process will produce a satisfactory effluent from a highly concentrated waste was confirmed by the Court, which stated in its final decree, "No nuisance has existed since June 16, 1946."

This plant treats all the waste from the manufacture of approximately 60 tons of baker's yeast each week. The plant consists of primary and secondary digesters, operated in series, with capacities of 357,000 and 263,000 gal., respectively; a high-rate trickling filter, 62 ft. in diameter and 7¼ ft. deep, filled with 2- to 3-in. rock, and dosed by a revolving distributor; and a final clarifier tank, 60 ft. in diameter, with a total capacity of 169,650 gal.

The digesters are operated at a temperature of 95° F., maintained by recirculation of their contents through a gas-and-oil-fired external heating unit; their detention periods are 3.5 and 2.6 days, respectively, at the average daily flow of 131,500 gal. They are operated under the "controlled digestion" patent, using the volatile acid test each morning.

One part of overflow from the secondary digester is mixed with approximately seven parts of effluent from the clarifier for application to the filter at a rate of approximately 18 m.g.a.d. The filter, covered to control odors and eliminate fly nuisance, has forced down-draft ventilation at a rate of 3,000 cu. ft. per min.

The clarifier has center inlet, peripheral discharge, is equipped with rotating sludge removal equipment, and has a retention period of 3¼ hr. Sludge removed from the clarifier is hauled to agriculture land as fertilizer.

Table I indicates the quantities of waste handled and the results obtained during a 4-day period selected at random from the operation reports. It

TABLE I. Quantities and Characteristics of Yeast Wastes Handled During a Typical 4-Day Period

Day	Waste Quantities		Filter Dosage (m.g.a.d.)	Clarifier Effl. Recirc. (m.g.d.)	Filter Ratio	Susp. Sol. (p.p.m.)		Total Sol. (p.p.m.)		5-Day B.O.D.[1] (p.p.m.)	Pop. Equiv.
	Raw (g.p.d.)	Over Filter (m.g.d.)				Total	Vol.	Total	Vol.		
1	131,000	1.252	18.1	1.124	8.8	530	500	7,600	4,500	2,750	22,100
2	134,000	1.260	18.2	1.124	8.2	3,100	1,740	7,100	3,900	2,680	20,100
3	129,000	1.260	18.2	1.130	8.7	1,000	740	3,400	1,960	3,040	21,600
4	132,000	1.252	18.1	1.121	8.6	1,595	845	8,390	4,290	3,280	31,100
Av.	131,000	1.256	18.15	1.125	8.6	1,556	956	6,372	3,662	2,937	23,725

[1] B.O.D. may range from 2,500 to 5,000 p.p.m.

should be noted that the average population equivalent is 23,725, whereas the city population is only 5,000. Table II gives some monthly average B.O.D. values of the effluents from the various treatment plant units. These indicate average reductions from the raw waste to the effluent of the primary digester, secondary digester, and clarifier of 67, 72, and 95.8 per cent, respectively.

The clarifier effluent is diluted by condenser water, reducing the B.O.D. to 44 p.p.m. before it is chlorinated and discharged to a small stream. No nuisance is created, the only evidence of its presence being the caramel color of the original molasses, which is not changed by the treatment processes.

The total gas production in the digesters averages close to 1,500 cu. ft. per hr., or 36,000 cu. ft. per day. The total addition of volatile solids is approximately 4,000 lb. per day. Thus, the average gas production is approximately 9 cu. ft. per pound of volatile matter added to the digesters. This quantity of gas has accompanied good operating results so long that gas production is used as a visual evidence of the quality of effluent leaving the plant.

TABLE II.—Monthly Average B.O.D. of Yeast Waste Disposal Plant Effluents (in P.P.M.)

Month	Raw Waste	Prim. Dig.	Sec. Dig.	Filter	Clarifier
Jan.	3,490	1,462	1,375	163	92
Feb.	4,420	1,450	1,421	238	207
Mar.	3,530	1,139	892	169	155
Apr.	2,314	618	470	119	89
Av.	3,258	1,074	921	157	137

The actual operating experiences reported herein confirm Mr. Davidson's statement that pretreatment by digestion followed by trickling filter treatment will produce a satisfactory effluent from distillery or similar wastes.

NEW ENGLAND INDUSTRIAL WASTES CONFERENCE

A New England Industrial Wastes Conference will be held at Massachusetts Institute of Technology on June 26–28, 1950, under the joint sponsorship of the Department of Civil and Sanitary Engineering, the New England Council, and the New England Sewage Works Association. The conference is designed to bring together representatives of industry, control agencies, and municipalities for general discussions of pollution abatement, as well as the water and waste problems of such specific New England industries as pulp and paper, wool scouring, cotton and wool dyeing and finishing, metallurgy and metal working, potato and milk processing, and leather tanning. The 3-day gathering will be concluded by a special symposium on future needs and developments.

Stream Pollution

SAMPLING FOR EFFECTIVE EVALUATION OF STREAM POLLUTION *

By C. J. Velz

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Sampling for effective evaluation of stream pollution involves three operations: collection of data; analysis of the data to determine specific self-purification characteristics; and projection of estimates for other conditions, principally the evaluation of expected stream quality at different drought severities and ranges of pollution load. All three operations are necessary to the establishment of a rational basis of stream control or a sound and economical pollution abatement program. With one good set of data defining one stable regime, by analyses it is possible so to define natural purification characteristics that stream quality can be computed for other drought severities and loads in less time and at less expenditure of effort and funds than by further stream sampling.

Although this paper will deal principally with the first operation, before collecting any data a clear purpose must be in mind. The type of analysis and the nature and extent of projection, whether for control or correction for water supply, bathing, fish and shellfish culture, recreation, or nuisance avoidance, have an important bearing on data collection. With these decided, collection becomes more than gathering a mass of heterogeneous information which may or may not be useful; actually, it is a design of a sampling procedure.

The scientific collection of data for stream analysis may be divided into three major categories: hydrologic factors, sources of pollution, and water-course sampling.

Hydrologic Data

Stream flow records are necessary to define the characteristics of the daily hydrograph and equally important to determine probability of drought severity, delineating the pattern of critical runoff.

Physical Characteristics of River Channel

The factors controlling deoxygenation, bacterial death rates, and reaeration are critically related to variation in the physical characteristics of the river channel. These physical characteristics are best obtained from frequent channel cross-section soundings. Sections at 500-ft. intervals would be ideal, but usually satisfactory results can be obtained at ¼-mi. intervals through the critical reaches and at ½-mi. intervals in the less critical zones. In taking sections it is not necessary to "split hairs" by use of surveying instruments, referring to sea level and tying in locations by traverse. Many sections along the course of the stream

* Presented at 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.; Oct. 17–20, 1949.

are preferable to a few, exactly defined. It is adequate to cross-section simply by soundings measured from the surface of the water and to determine widths by a rope stretched across the channel. The location of the cross-section stations can be approximated from physical features along the channel (bridges, sharp bends, islands, or tributaries), identified in the field and marked on a good map. In moving by boat between stations, additional soundings should be made along the channel to detect any unusual pools or deep pockets.

The time at which each sectioning station is occupied should be noted so that the surface of the water can be referred to a gage height corresponding to the prevailing river discharge. Soundings then can be adjusted to other stream flow conditions by use of the rating curves at stream gaging stations within or near the reach involved.

The main purpose of channel cross-sections is to determine occupied channel volume associated with a particular steady stream flow. It is then possible to compute the displacement time. This provides the all-important time of passage of pollution from reach to reach. Integrating the various loads with this time of passage affords a measure of the pollution load satisfied or the bacterial survivals. In addition, cross-sections provide the mean channel depths applicable to each reach, which are so important in computing reaeration. They also provide the variation in mean velocity through various reaches, from which it is possible to evaluate potentialities of sludge accumulation and scour. The absence of sludge deposits at the time soundings are taken is not assurance that sludge deposits may not be involved. Hydraulic characteristics of certain reaches of the stream may be so critically balanced that during a protracted drought period velocities may be sufficiently reduced to permit sludge deposits to occur and accumulate, but at flows somewhat above drought conditions, deposits might be scoured to such an extent as not to be detected during sounding operations.

Auxiliary information concerning physical characteristics can be obtained from determination of time of passage by methods other than volume displacement. The staff of the Tennessee Valley Authority has developed a potentiometric method whereby a waste or salt slug can be followed and timed down the course of a stream. This procedure is particularly valuable in wide and deep streams or pools where short circuiting may be involved. In small, shallow streams comparable results can be obtained by introducing a dye. Before too long it is hoped that instrumentation will be developed to a stage where isotopes of short life may be introduced and traced in a natural water course. The old practice of using floats is to be discouraged as it does not provide reliable results, particularly in tidal waters or in large, deep rivers.

Sources of Pollution

The second primary source of data, pollution load, should be obtained from an onshore survey. Municipal pollution is readily determined from tributary population. The industrial waste load is usually the most difficult factor and entails a waste survey of major industries. In running B.O.D. determinations there should be a check for immediate demand and a differentiation between the fraction of the B.O.D. in suspended solids form subject to sludge deposit and that fraction in colloidal or dissolved form remaining in the flowing stream. In addition to the standard 5-day B.O.D., rate curves extending to 20 days should be run for the major industries that are suspected of having unusual wastes. Also, it may be necessary to employ different dilution waters.

An attempt is sometimes made to bypass the onshore survey by determin-

ing the pollution load from the B.O.D. of the receiving water. Obviously, the B.O.D. results of the river water cannot be used both to determine the load and to check on the load. Furthermore, the varying runoff patterns in the water course set up substantial variations in population equivalents simply by virtue of volume changes. Also, it is difficult to obtain a representative sample in the water course below a source of pollution and a small error in B.O.D. associated with a large runoff results in a large error in population equivalent. A much more reliable measure of pollution load can be obtained from a direct survey at the sources, reserving the B.O.D. of river water samples as a check against the onshore loads.

Stream Sampling in Fresh Waters

Types of Samples

In sampling a fresh water stream, the samples usually required are for B.O.D., D.O., pH, and temperature; and, if bacterial quality is under consideration, coliform concentration. Where fish life is of major importance, other chemical examinations and biological assays may serve as auxiliary data, but where organics are involved, are not substitutes for the D.O. test. Generally, oxygen depletion is a more sensitive criterion than toxicity concentrations.

Location, Number, and Intensity of Sampling

The first question usually asked is: How many samples must be taken? In a statistical sense there is no answer to this question without foreknowledge of the variability of the phenomena to be sampled and the precision desired. Rivers are dynamic and subject to wide variation in time as well as from place to place along the course. In some instances information from previous surveys indicates the nature of variability and serves as a guide for the initial design of a program. It must be recognized, also, that there are so many uncontrollable variations at play that any design of a sampling program inherently should remain flexible.

Ordinarily, too many stations are established, with an insufficient number of samples collected at any one. A few locations with sufficient number of samples to define results in terms of statistical significance are much more reliable than many stations with only a few samples at each. At best, stream sampling is subject to considerable variation; hence, if valid conclusions are to be drawn from the data, enough samples must be taken to define the variability by statistical treatment and determine the degrees of confidence in any mean condition.

The same holds true with respect to intensity of sampling. Too frequently samples are spread over a long time interval, during which river regime is subject to a wide variety of conditions. Attempting to sample all conditions by grab samples here and there, now and then, usually defines no condition and, in fact, may be very misleading. Averaging of such noncomparable results is a dangerous procedure. It is much better to concentrate during a short interval with intensive sampling when the river regime is stable during a steady hydrograph.

Factors Affecting Stream Sampling

A few examples will illustrate the many factors affecting sampling and difficulties of obtaining representative samples.

1. Sampling in Relation to Daily Hydrograph.—The most important factor affecting sampling is the daily hydrograph. Figure 1 shows a highly flashy daily hydrograph where runoff is almost constantly varying. The arrows indicate days on which samples were taken. It is noted that most of these samples were taken during periods of radical variation in flow; it

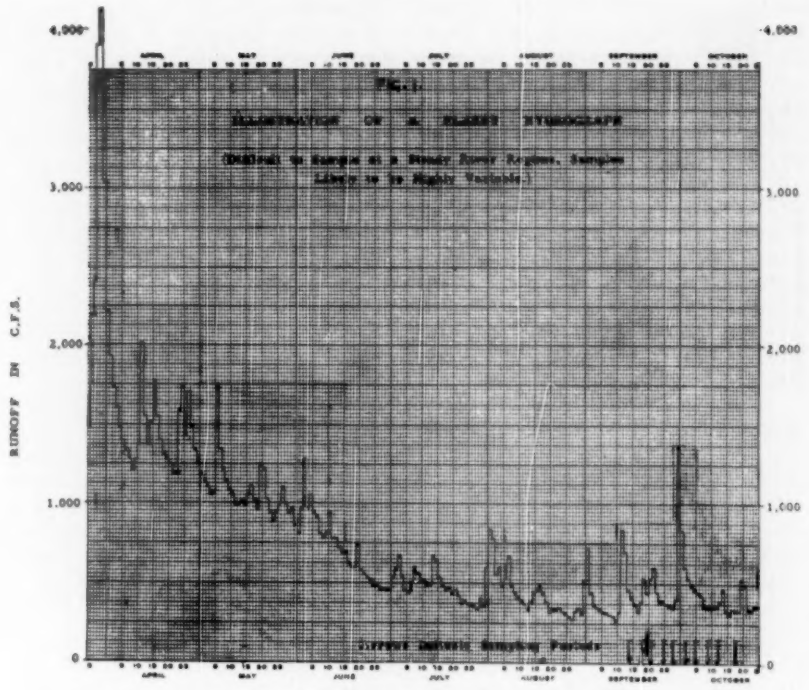

FIGURE 1.—A flashy hydrograph.

cannot be expected that an average of these values would reflect a steady river regime equal to the average of the daily discharges during these days. The ideal period for sampling is during a steady runoff pattern, but sampling should not start until the steady hydrograph has established a stable river regime, and this requires at least a period equal to the time of passage through the critical reach. When such a steady flow is established, a week of intensive sampling is usually adequate to provide 16 to 20 samples at each station.

Figure 2 shows a flashy hydrograph, but with an ideal sampling period during the month of September when a period of steady river flow prevailed, uninfluenced by previous flash flows. Unfortunately, one cannot predict exactly when such a steady river regime will be established, but from a statistical analysis of past flow records the most probable season when such periods occur can be ascertained; also, long-term forecasts of the Weather Bureau are now available. The point is: Do not waste energy in sampling during radically fluctuating flow; rather during such periods concentrate upon other aspects, keeping the organization in readiness to make a quick switch to intensive sampling as soon as the opportunity to obtain a steady river regime becomes apparent.

In this connection, it is obvious that a day-to-day or almost an hour-to-hour contact must be established with the U. S. Geological Survey to supply gage heights and runoff records of the various gaging stations. The staff of U. S. G. S. is always very cooperative in supplying such information.

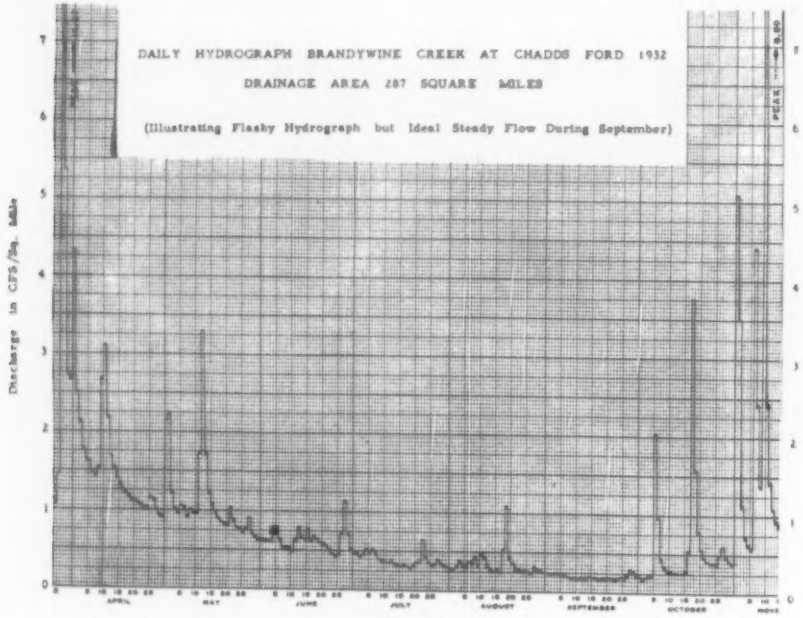

FIGURE 2.

2. Sampling in Relation to Sources of Pollution and Tributaries.—Location of stations in relation to sources of pollution affects stream sampling results. If a station is established at or immediately below a large source of pollution, it is very probable that sampling results, influenced by streak pollution, will be erratic. It is better to locate the sampling station some distance downstream, where dispersion throughout the section has been reasonably complete. Even then, care should be taken if the stream is sluggish and wide to test for variability, and if detected, it may be necessary to sample at a number of points across the section. This, of course, adds to the number of samples required.

Similarly, sampling stations should not be located immediately below a junction of a tributary. It is better to locate the station on the main stream above the junction and to establish a secondary station on the tributary just above its mouth. Otherwise, the sampling station on the main water course should be located sufficiently downstream to insure complete dispersion throughout the cross-section.

3. Sampling in Relation to Physical Characteristics and River Developments.—Physical characteristics of some rivers make it necessary to take samples at different points transversely across the channel and at different depths. This greatly adds to the number of samples required to obtain a reliable mean for the section. In some instances, river developments (such as power dams and storage pools) introduce short circuiting and stratification.

One of the most troublesome variations in sampling introduced by river developments is the practice of hydroplants to operate with considerable variation throughout the 24 hr. of a day. This sets up a radical diurnal variation in runoff, such as is illustrated in Figure 3. Although the daily

average discharges throughout the period of a day or week may indicate almost a steady runoff, there is a cyclical variation throughout the hours of the day. This sets up a series of pulsations in discharge which persist down the course of the river and make representative sampling exceedingly difficult. It becomes necessary then to occupy a sampling station throughout 24-hr. periods, taking samples once an hour or once every 2 hours to pick up the radical variations throughout a cycle.

4. Sampling in Relation to Waste Discharge Practice.—Another factor which frequently leads to fluctuation in sampling results is the operating pattern of the major industries. Some industries operate 7 days a week, 24 hours a day, on relatively continuous discharge basis, with but only minor variation throughout the day and from day to day. Other establishments shut down completely over the weekend. Still others may operate on an 8-hr. shift and possibly discharge waste on a batch basis. Monday morning samples following a week-end shutdown would hardly be representative. Another factor to watch for is the matter of holiday or vacation shutdown. Following such a shutdown it may take a week or more before production is normal. Such a shutdown, however, affords a check on industrial load; but if sludge deposits are involved, the carry-over of demand from past accumulations is a major factor to be considered.

5. Abnormalities in Natural Purification Characteristics.—Abnormalities in natural purification characteristics of a stream influence the location of stations and number of samples to be collected. These situations cannot al-

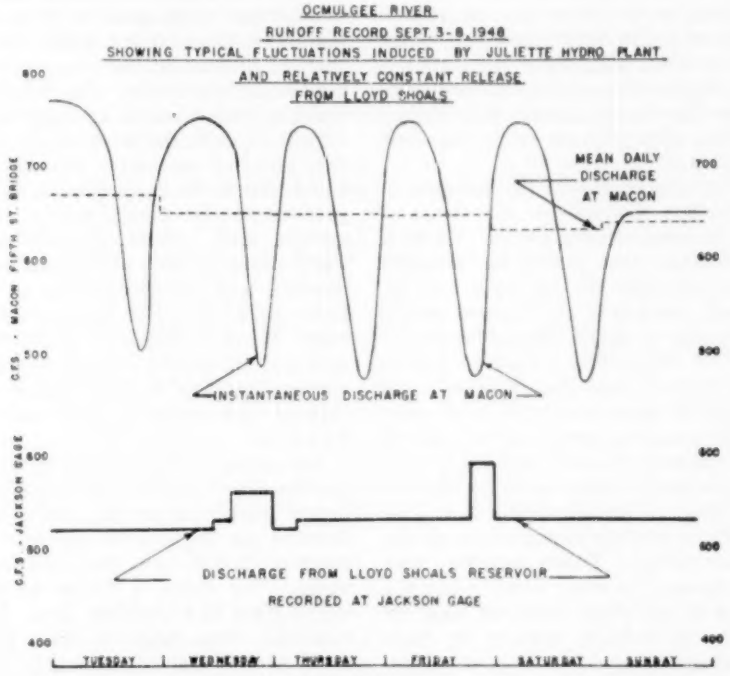

FIGURE 3.

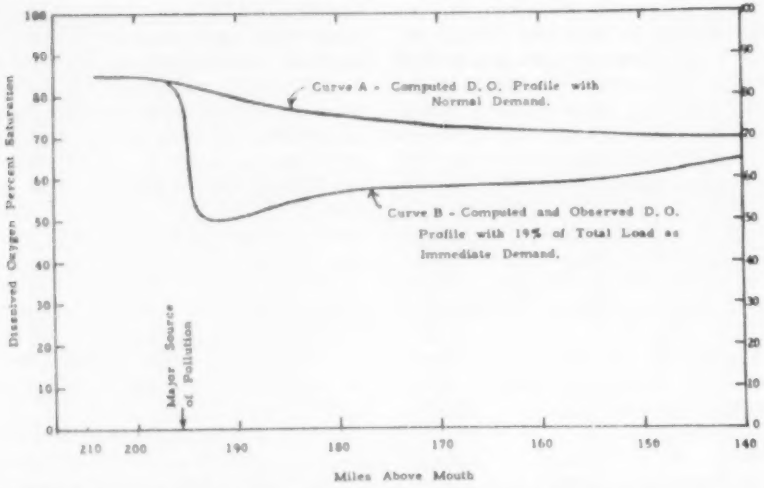

FIGURE 4.—Influence of immediate demand on shape of dissolved oxygen profile.

ways be foreseen. If they are suspected, it is highly desirable to take a test run to determine the general characteristics before deciding on location of sampling stations. Four major abnormalities may be encountered: immediate demand, sludge deposits, biological adsorption on the stream bed, and algae.

Figure 4 illustrates the influence of immediate demand on the shape of the dissolved oxygen profile. Curve A represents what would be normally expected from the pollution load involved, whereas Curve B shows the abnormality in shape induced by 19 per cent of the pollution load present in the form of immediate demand. An industrial waste survey, if made prior to the sampling, would detect presence of immediate demand, and the location of sampling stations could be planned to reflect the abnormality.

Sludge deposits may produce similar abnormalities. These, however, may not necessarily occur directly below a point of pollution, but may arise by virtue of reduced velocity in pools along the course of the channel, allowing suspended solids to deposit and accumulate. The pool need not be large; in fact, the greatest abnormality is associated with pools of short detention period of a few hours, but of velocity sufficiently low to permit deposit and accumulation. The difference between what is normally expected in oxygen sag with the short time of passage and that associated with the demand from sludge accumulation is then pronounced. No doubt, in some river surveys such pocket deposits with sharp drops in D.O. profile are never detected and the abnormality of the lower end of the profile remains a mystery. The only assurance of detecting such a situation and locating sampling stations properly to reflect it, is the channel cross-sectioning previously referred to.

An unusual phenomenon at times associated with shallow streams is biological adsorption on the stream bed. Growths on the bed extract and accumulate B.O.D. from the overflowing water. The action is similar to that taking place in a trickling filter. In a relatively short reach of river, from 60 to 80 per cent of the B.O.D. may be extracted from the overflowing wa-

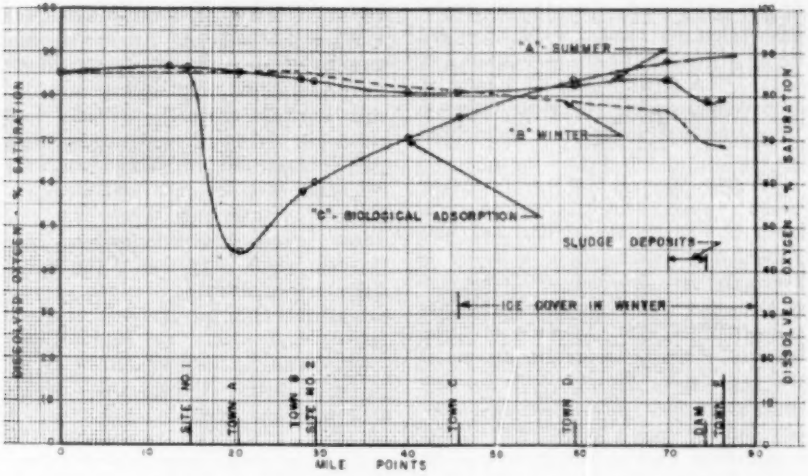

FIGURE 5.—Influence of biological adsorption of growths on the stream bed on shape of dissolved oxygen profile.

ter, building up an equilibrium storage in the zoogleal growths, such that the demand from the accumulation is equal to the daily load extracted. This produces a very sharp drop in D.O. profile far beyond what can be accounted for by the time of passage through the reach, such as illustrated in Figure 5, Curve C. The high demand from the accumulated storage should not be construed, however, as high-rate in biochemical oxidation of the organic matter. The rate is generally normal for aerobic decomposition. The excessive demand results from the normal rate working on an accumulation in excess

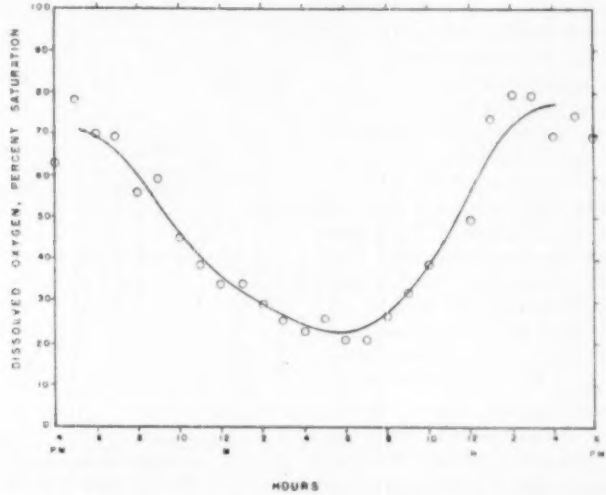

FIGURE 6.—Observed dissolved oxygen in Wabash River, showing influence of algae.

of one day's load. Usually, biological adsorption on stream beds does not occur where depths are more than 3 or 4 ft. The abnormality of biological adsorption may not always be detected. Like sludge deposits, it is influenced by scour.

Freshets in small flashy streams may produce high velocities sufficient to scour completely the stream bed, and a period following such a scour is necessary to re-establish biological growths and accumulate an equilibrium storage of B.O.D. Another situation may occur where, in certain seasons of the year, these growths will die and dislodge in large quantities and actually during such a period will impart a pollution load to the stream to be satisfied along the course of travel through the lower reaches. These factors must be taken into consideration in attempting to sample and evaluate such an abnormality.

Finally, there is the well-known abnormality of influence of algae. Figure 6 illustrates the effect of algae on dissolved oxygen content throughout a 24-hr. cycle of sampling. During the daylight hours algae give off oxygen; during the night hours they do not, and may utilize oxygen. A single sample taken at a station during the day would hardly be representative. In fact, where algae are involved the problem of stream analysis becomes highly complicated. Certainly it is essential, where such marked differences are apparent, that samples must be taken at frequent intervals (one each hour or two) during 24-hr. cycles. Variations due to algae are most pronounced on sunny days; cloudy dark weather may result in conditions almost normal. A freshet may flush the stream and if a steady river regime can be established quickly, it may be possible to obtain uninfluenced samples before heavy growths are re-established. In deep rivers the temporary surface effect of algae may be avoided by taking samples at lower depths.

Sampling Tidal Waters

What has been said concerning factors influencing sampling in fresh waters applies equally to streams discharging into the ocean or into tidal estuaries. In addition, there are further complications arising from the variation of tides and tidal currents. Figure 7 illustrates three types of tides: the semi-daily tide for New York Harbor, which is typical of the North Atlantic; the daily tide, which is typical of the Gulf of Mexico; and the mixed tide, typical of the Pacific Coast.

In addition to the moment-to-moment variation in tide through a day associated with the apparent movement of

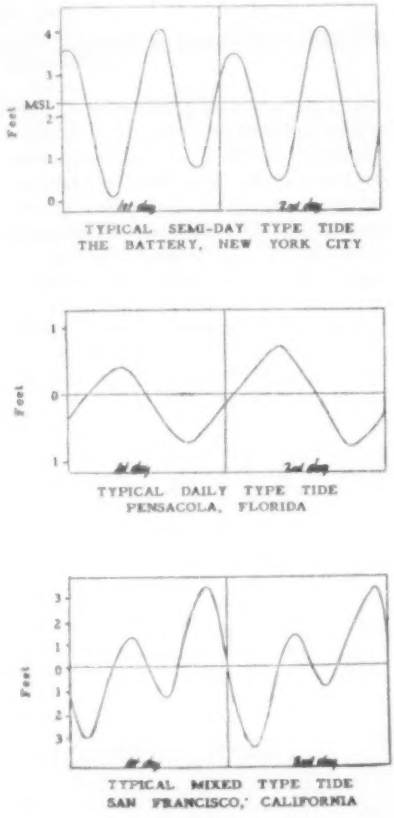

FIGURE 7.

the moon around the earth, there are also day-to-day variations, depending on the position of the moon relative to the earth and the sun. The most noticeable variation from day to day is that related to the moon's phase, which has a cycle of 29½ days. As shown in Figure 8, during new and full moon the range is considerably above the average; during the first and third quarters, substantially below the average. The moon's declination, which has a cycle of 27⅓ days, induces diurnal inequality between the morning and the evening tides. In some areas this is pronounced, whereas in others the inequality is minor. The influence, however, is apparent in Figure 8, a

PREDICTED VARIATION IN TIDE
NEW YORK HARBOR, OCTOBER 1949
Illustrating Influence of Moon's Phase on Range, and Moon's Declination on Diurnal Inequality

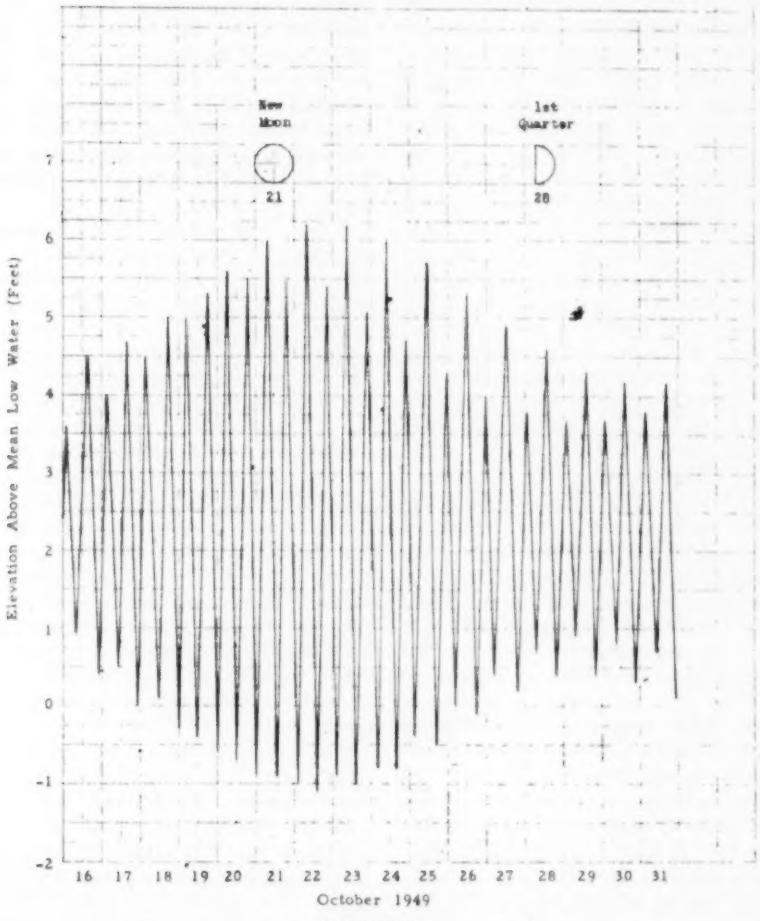

FIGURE 8.

difference in the range showing in the two tides in a day. There are other long-term factors, as well as complicating influences such as wind and physiographic features, which can radically alter the normal tidal pattern. The dominant influences, however, are the daily or semi-daily cycle, the cycle of the moon's phase, and the cycle of the moon's declination.

The vertical rise and fall of the tide brings about a corresponding horizontal reversal in tidal current. Thus, in sampling at any one position with reference to a fixed land location, the body of water is constantly oscillating, ebbing and flooding. Furthermore, fresh water runoff from the stream's drainage area influences the extent of oscillation and introduces still other complications. If there were no land-water runoff, the translation of the ebb flow would be counterdistanced by the flood and there would be no net movement toward the sea. The moment there is any land-water runoff the ebb flow translation exceeds the flood, thereby introducing a net movement toward the ocean which increases as land-water runoff increases. It is this net movement which constitutes the time of passage through the tidal reach to the ocean.

In addition, where a land-water stream discharges into the ocean the lower reach of the river experiences intrusion of sea water far beyond the range of the flood current, forming a mixture of sea and land water. These brackish waters will range from 100 per cent sea water at some location beyond the outlet into the ocean to 100 per cent land water at a location many miles upstream, depending on depth, formation of the river channel, and the rate of land-water runoff. A salinity gradient is established through this brackish reach with the sea-water content gradually diminishing along the upstream course to its upper limit at the 100 per cent land-water location. The land-water discharge to the sea actually is a complex process of interchange of land and sea water through the brackish reach. The net effect of this interchange may be resolved into two opposite net flows, one equivalent to the land water going seaward and the other equivalent to the sea water intruding upstream through the brackish reach, discharging sea water into the downward land-water flow at such intervals and in such quantities as to provide the observed salinity gradient. Thus, this hypothetical sea-water river is a great flow near the ocean but gradually diminishes in volume as it proceeds upstream, vanishing at the upper end of the brackish waters. As the land-water flow diminishes, the brackish reach is lengthened and extends farther upstream; conversely, as land-water flow increases, sea-water intrusion is held back and the brackish reach is shortened.

With these complications, random sampling in tidal waters is of little value. What is required is controlled sampling, taking into consideration the major variables. The key to the position and division between land-water and sea-water flows at any location in the brackish reach is the salinity content; hence, salinity becomes a basic measurement in sampling of all tidal waters. All that has been said about the influence of runoff has now a double significance, because land-water variation also affects ebb-flood translation and the extent of sea-water intrusion. It becomes doubly important, therefore, to control these influences by confining sampling to a period of steady runoff, allowing adequate time to insure establishment of a steady regime.

The second variable to control is the daily variation associated with the moon's phase. Fortunately, this is a periodic phenomenon which is predicted in the tide tables; thus, sampling definitely can be planned to coincide with one distinct phase. This is particularly important where water

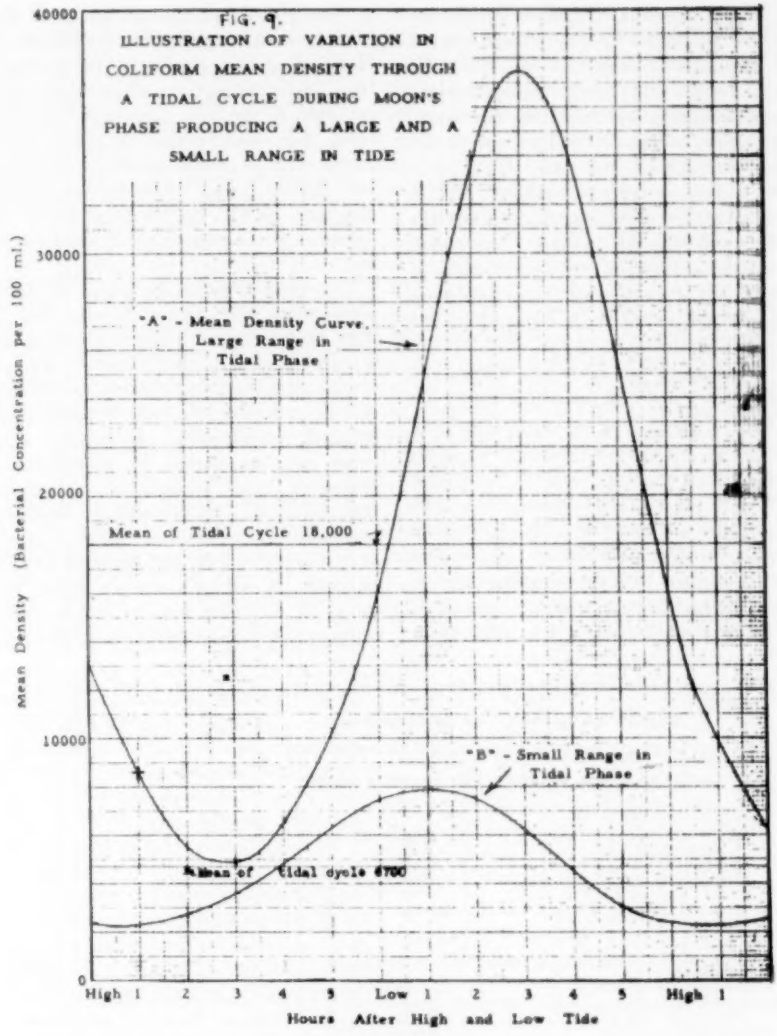
FIG. 9.
ILLUSTRATION OF VARIATION IN COLIFORM MEAN DENSITY THROUGH A TIDAL CYCLE DURING MOON'S PHASE PRODUCING A LARGE AND A SMALL RANGE IN TIDE
Mean Density (Bacterial Concentration per 100 ml.)
40000
30000
20000
10000
0
"A" - Mean Density Curve, Large Range in Tidal Phase
Mean of Tidal Cycle 18,000
"B" - Small Range in Tidal Phase
Mean of Tidal cycle 6700
High 1 2 3 4 5 Low 1 2 3 4 5 High 1
Hours After High and Low Tide

FIGURE 9.

quality profiles are steep along a course and are radically influenced by the extension of the flood and ebb currents. Figure 9 illustrates the importance of such concentrated sampling in polluted waters, as the high range phase in tide produces a distinctly different quality level from that of the low range. Obviously, samples from these two phases cannot be lumped, in a statistical sense, it being much better to define the two extremes as illustrated, and from these draw conclusions about transitional phases. In comparing quality of such waters, results are comparable only when samples are taken during comparable ranges in tidal phase.

There remains a major factor peculiar to tidal waters which cannot be controlled; namely, the semi-daily tidal cycle, inducing moment-to-moment changes. It becomes necessary, therefore, to sample at frequent intervals throughout the daily tidal cycle (each hour or each two hours). Thus, the complete variation throughout the tidal cycle can be defined, from which a mean value can be determined as well as the maximum and minimum ranges associated with the end of the flood and the end of the ebb. If 16 to 20 samples can be taken within the same 2-hr. position in a tide cycle, on different days but at approximately the same moon's phase, then by plotting on probability paper a reliable estimate of the true mean value can be obtained where the distribution line intersects the probability of 50 per cent. Figure 10 illustrates such a plotting producing a "mean density" (M.D.) of 8,600 per 100 ml. This M.D. is then plotted at the mid-point of the 2-hr. interval as point (a) on Figure 9. Mean densities similarly determined from distributions of values taken during each of the 2-hr. intervals form the basis for constructing a tidal cycle curve such as shown in Figure 9. Unless M.P.N.'s are reduced to mean densities it will be found difficult to define or even recognize a tidal cycle curve.

One compensating influence of tidal phenomena with respect to sampling is that there are no sudden changes in quality profile. The extensive range of ebb and flood flow acts as a leveling device, reducing changes in quality to gradual transitions. Sampling stations can be spaced at considerable distances with reasonable assurance that there will be no abrupt changes intervening. This advantage, however, hardly offsets the increase in the number of samples which must be taken at any one station if the tidal influences are to be properly evaluated.

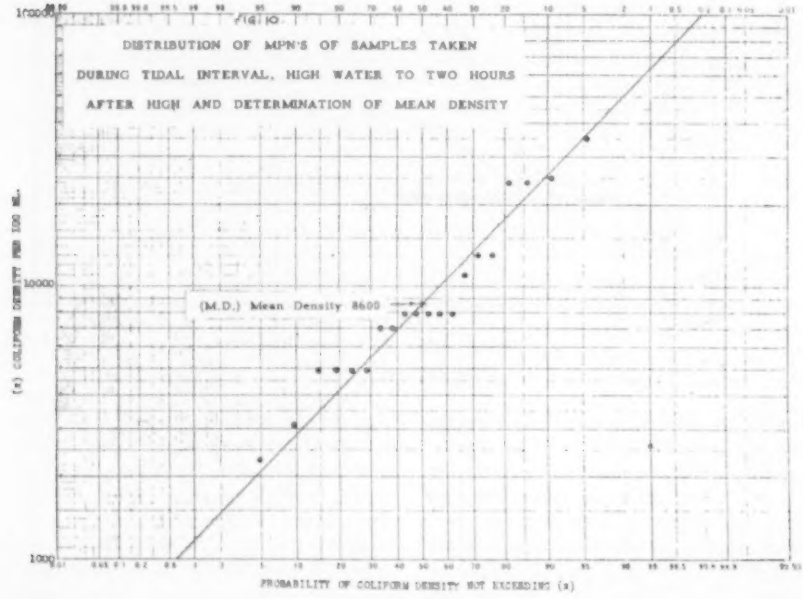
DISTRIBUTION OF MPN'S OF SAMPLES TAKEN
DURING TIDAL INTERVAL, HIGH WATER TO TWO HOURS
AFTER HIGH AND DETERMINATION OF MEAN DENSITY
(M.D.) Mean Density 8600
10000
1000
PROBABILITY OF COLIFORM DENSITY NOT EXCEEDING (a)

FIGURE 10.

Variations Associated with Laboratory Procedure

The laboratory procedure employed affects test results for water quality in certain types of determinations (such as B.O.D. and, particularly, coliform concentration). The laboratory procedure itself induces variations in results quite apart from real variations in the bacterial density of the body of water sampled. Too frequently, the variations associated purely with limitations of bacteriological procedure are erroneously considered real variations in quality. The deviations associated with laboratory technique follow quite definite laws of probability, but in order to differentiate them from the true variations in bacterial density it is essential to have sufficient sampling data to permit of their statistical evaluation.

For an appreciation of sampling requirements for reliable determination of bacterial quality of fresh or tidal waters, it is necessary first to have an understanding of the difficulties and limitations of bacterial enumeration by the dilution method.

Bacterial enumeration by the dilution method is a statistical process. The usual practice is to report test results of individual samples in terms of "most probable numbers" (M.P.N.). This sounds very precise. Actually, probability of the most probable number with the usual test procedure is of a very low order and is subject to wide variation. An M.P.N. of a single sample usually has very little significance. A reliable measure of quality can be derived only from a series of samples subjected to statistical treatment, determining an estimate of the true mean density.

True mean density is defined as the total number of coliforms in the body of water sampled divided by its total volume. Test results of individual samples taken from this body of water expressed as M.P.N.'s will vary about the true mean density in a definite manner, depending on test procedure. For example, Line A (Figure 11) illustrates the variation expected for a test procedure employing 5 portions in each of 3 decimal dilutions for samples taken from a body of water having a known fixed mean density of 1.0 per ml. The distribution of M.P.N. values is logarithmically normal. The mid-point (50 per cent) of the distribution coincides with the true mean density (1.0 per ml.); 5 per cent of the test results are expected to be equal to or less than 0.39 per ml., whereas 95 per cent are expected to be equal to or less than 2.5 per ml. Similarly, if only one portion in each of 3 decimal dilutions is employed as the test procedure, variations in M.P.N.'s of individual samples taken from this same body of water can be expected to fall along line B (Figure 11). The mid-point (50 per cent) of the distribution again coincides with the true mean density (1.0 per ml.), but the variation about the mean density is greater; 5 per cent of the test results can be expected to be equal to or less than about 0.12 per ml., and 95 per cent equal to or less than 8.0 per ml.

As the number of portions in each of 3 decimal dilutions increases, the distribution lines flatten,* as shown in Figure 12. If a large enough number of portions is employed, all the M.P.N.'s of such samples would approach a value equal to the true mean density. An ideal sample would be one which measured the true mean density directly in this manner. This would greatly reduce the number of samples required, but unfortunately would require employing a prohibitively large number of portions in each sample. However, it will be noted that the same mean density can be derived

* The slope of the logarithmically normal distribution is represented by $\sigma_{(Log)}$, which varies with n, the number of portions employed, as

$$\sigma_{Log} = \frac{0.5487}{\sqrt{n}}.$$

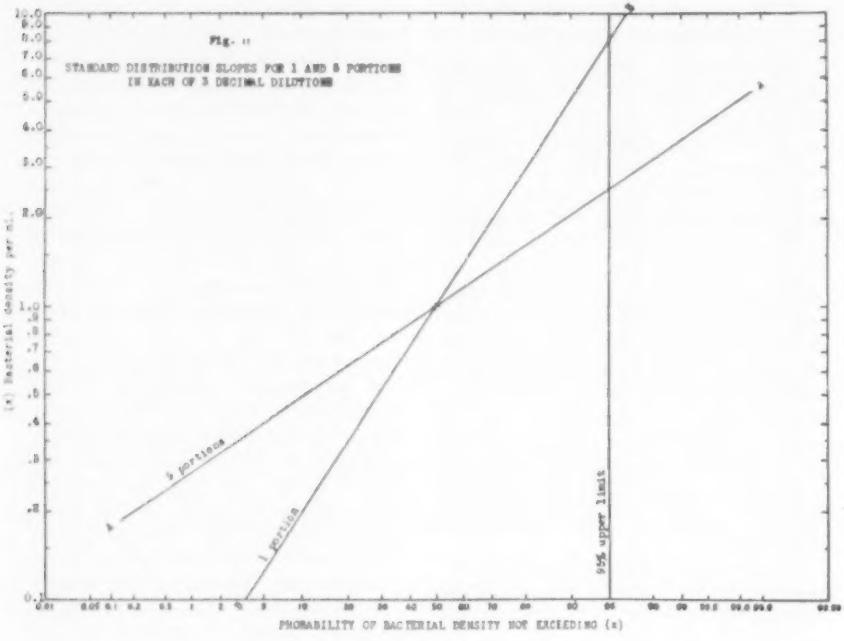
Fig. 11
STANDARD DISTRIBUTION SLOPES FOR 1 AND 5 PORTIONS
IN EACH OF 3 DECIMAL DILUTIONS
(x) Bacterial density per ml.
5 portions
1 portion
95% upper limit
PROBABILITY OF BACTERIAL DENSITY NOT EXCEEDING (x)

FIGURE 11.

from samples employing a small number of portions providing a sufficient number of samples are taken from the body of water to develop a well-defined line through the full range of the distribution. Where this line cuts the mid-point (50 per cent) the true mean density is determined.

Thus, two alternatives are available —either a few samples employing a large number of portions in each dilution, or a large number of samples employing a few portions. The former would be the better protection against misinterpretation of test results, as it would provide directly a close estimate of the mean density. Such sampling would be particularly applicable to polluted tidal waters where quality is constantly changing due to flood and ebb translation past the sampling location. However, from a practical standpoint of laboratory requirements, generally the latter practice is adopted, usually employing 5 portions in each of 3 critical decimal dilutions. Generally, the difficulty with this is that when so small a number of portions are employed, also too few samples are taken, with the result that no attempt is made to derive from the distribution of the series what is really sought, namely, the true mean density. This too frequently then leads to the practice of regarding the M.P.N.'s as real measures of density and fallaciously interpreting the mere variations in M.P.N.'s as real changes in water quality.

Obviously, to detect a real change in water quality it must be demonstrated from sampling that there has been a significant change in true mean density, not merely variations associated with test procedure. It follows, therefore, that test results reported as M.P.N.'s must be reduced to mean densities before interpretations are

made concerning quality. Usually, 16 or more samples are required to reasonably define a normal distribution on log-probability paper and determine a mean density.

A procedure for reducing bacterial sampling data to mean densities and determining significant changes in real quality is set forth in the Addendum. The habit should be acquired of thinking in terms of mean density (M.D.) and not in M.P.N. Any attempt to evaluate bacterial quality or trends short of this (or equivalent) procedure is purely speculative.

Conclusion

In sampling for stream analysis there is no short cut, if reliable results are desired, but the statistical approach to sampling affords a maximum of information with a minimum of cost in time and funds. From one reliable set of data at one steady river regime, the effect of other levels of runoff and pollution load can be computed.

Addendum

For a series of samples employing multiple portions in each of 3 decimal dilutions, it is possible to evaluate bacterial density in terms of mean density (M.D.). If such series are taken over an interval of time, it is also possible to determine if the density remained stable or if it was subject to change, and if so, how much. This is readily determined graphically by arranging the M.P.N.'s of individual sample test results in order of magnitude; numbering them serially; assigning probability plotting positions as $m/(n+1)$, in which m is the serial number and n is the total number of values to be plotted; plotting on log-probability paper; and fitting a straight line to the distribution. The mean density (M.D.) is obtained directly where the line of the distribution intersects a

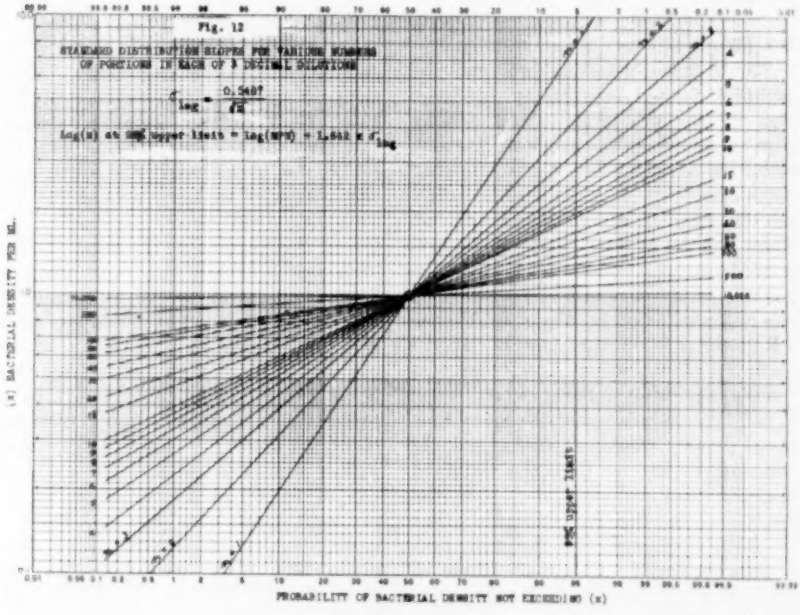
Fig. 12
STANDARD DISTRIBUTION SLOPES FOR VARIOUS NUMBERS
OF PORTIONS IN EACH OF 3 DECIMAL DILUTIONS
PROBABILITY OF BACTERIAL DENSITY NOT EXCEEDING (x)

FIGURE 12.

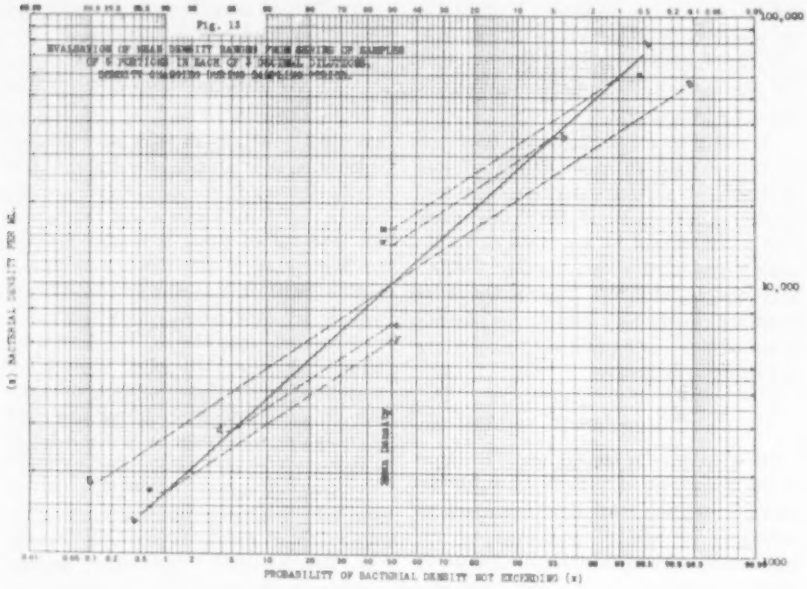

FIGURE 13.

probability of 50 per cent. As was shown previously, this coincides with the theoretical true mean density.

The slope of the line indicates the stability of the mean density. If there was no change in the mean density during sampling the slope of the distribution should be equivalent to that determined by $\sigma_{(Log)}$ depending solely on the number of portions employed. This standard slope defines the expected variation associated with the particular test procedure employed and can be transferred readily from Figure 12 to the distribution graph. If the observed distribution line from test results is parallel to the standard slope, it can be concluded that the mean bacterial density remained unchanged. If the slope is steeper than the standard slope, it can be concluded that the variation in density exceeded that normally expected for the test procedure employed and a real change in level of mean density took place during the sampling period.

The range of such a real change in mean density is readily obtained graphically (see Figure 13). Line A—A represents the distribution of observed test results employing 5 portions in each of 3 decimal dilutions. Line B—B represents the base slope expected for a 5-portion 3-decimal dilution test procedure. The mean density associated with any probability not exceeding that density is readily obtained by projecting parallel to the base slope a density at that probability from Line A—A to the mid-point of the distribution. For example, Line A—A intersects a probability of 99 per cent at point a (61,000); from this point extend parallel to B—B to a probability of 50 per cent, locating point x (16,000). This is to say that with a 5-portion test procedure a density of 61,000 at a probability of 99 per cent must have resulted from a mean density of 16,000; hence, the probability is 99 per cent that the mean density did not exceed 16,000. Similarly, other mean densities are projected to points w, z and y.

DISCUSSION

By Robert N. Clark

Chief Public Health Engineer, Tennessee Valley Authority, Knoxville, Tenn.

In discussing the statistical approach to stream analysis, Professor Velz has described many of the basic features of a stream study program. Although much of his discussion deals with sampling, he emphasizes the importance of adequate mathematical and statistical analysis, and certainly, if stream data are to be useful, they must be worked over and put into a form that permits accurate prediction of what can be expected as stream conditions vary.

If the study is to be statistically sound, certain common-sense rules must be observed. One rule, of course, has to do with the limits of accuracy which should be observed. Such limits are usually set either by choice of sampling method or by choice of analytical method, and it hardly seems logical to apply a refined mathematical treatment to data which are not within, say, 5 per cent of the most probable value to begin with. Consequently, it is useful to take a careful look at the whole chain of events, including sampling, laboratory methods, mathematical analysis, formula derivation, and finally projection. The weakest link in the chain sets the limit of accuracy for the whole study, and it is good discipline and good economy to apply this limit ruthlessly.

A second common-sense rule is to discard data that are obviously wrong. This follows the statistical axiom that very large errors do not occur; when the deviation is very large, it is a mistake and not an error. It is not difficult to determine when an individual observation is out of line, and there are definite statistical rules or criteria to follow in such cases. Obviously, the use of wrong data, either for developing averages or for formulating trends, may seriously affect the final usefulness of the study.

A third rule is to fit the whole program of sampling, analysis, and projection to the particular job at hand. In the study of streams, for example, it is possible to use either the "shotgun" or the "bullseye" approach, and it is hardly necessary to equip a 12-gauge smoothbore with telescopic sights. The purpose of the study must be kept constantly in mind. If simple qualitative evidence is all that is necessary, for example, to support a legal complaint that discharge of sewage makes a certain creek stink, then a single, but conclusive, program of sampling, analysis, and description is all that is necessary.

Another fundamental rule, and one that seems to escape attention all too often, is to have enough data to support the conclusions. Admittedly, the application of this rule is tricky, for although on the one hand the most elementary texts on statistical procedures deal carefully with the statistical basis for sampling, on the other hand the most exhaustive works on stream sanitation do not fully cover the things that can happen in a stream.

The orderly arrangement of facts and the formulation of general conclusions is an interesting process and one which frequently brings out previously unknown information. Recently the Tennessee Valley Authority (TVA) conducted a survey of a long stretch of the main river to determine the bacterial quality of the water under varying conditions. The results, in terms of most probable number of coliform organisms, were analyzed, giving consideration to dilution, time of water travel, and location of points of sewage pollution, and were fitted into a typical coliform deathrate pattern. However, at one point the data con-

clusively showed the addition of coliform bacteria where none were anticipated. Back calculation indicated that the contribution was about equal to the sewage discharge from 400 persons, and the briefest sort of survey quickly revealed the existence of a small community sewer outfall, a record of which was previously lacking in TVA files. The incident was particularly amazing because the diluting flow in the Tennessee River at the time was about 27,000 cu. ft. per sec. It illustrates quite dramatically the reliability of sound statistical practices.

With regard to the number of sampling points, and the study to be given at each point, these factors must be considered in the light of each particular study. TVA has used and, to some extent, developed a system of sampling to reveal what happens to pollution in the stream. This involves the identification of a given mass of water, usually a 24-hr. flow, as it moves downstream, and the collection of samples from the same mass or prism at successive downstream points. In this way a great deal of "bullseye" information can be obtained, including not only the effects of self-purification processes, but also the results of side pollution, tributary dilution, and other factors that are difficult to evaluate under a less precise system of sampling.

In considering the desirability of using a statistical approach to stream analysis, it must be kept in mind that a stream presents a maze of variables—physical, chemical, and biological—the analysis of which demands the application of the laws of probability. Under such conditions, a single observation is virtually worthless; the development of a true picture and the projection of a reliable prediction require the careful and accurate application of statistical laws.

POLLUTION PREVENTION BY REUSE OF WASTE WATERS

Recent completion of a new treatment plant to rectify waste water from the Alan Wood Steel Company's plants at Conshohocken, Pa., will relieve a major industrial pollution load from the Schuylkill River. The treatment plant, claimed to be the most modern of its kind and the first to be built along the Schuylkill River to comply with Pennsylvania's water purification program, not only eliminates the discharge of contaminating waste products from the steel mills to the river, but also acts as a water conservation unit.

The installation enables the company to repeatedly circulate the treated water to the mill supply system. Water is drawn from the river only to make up for losses and to keep the system up to normal operating capacity. Waste waters from the steel mills are discharged to the river only when the ready supply exceeds demands, and then only after treatment to meet stream condition requirements.

The plant, which was under construction for more than a year, cost upwards of $775,000.

DISPOSAL OF SEWAGE INTO TIDAL WATERS *

By Richard G. Tyler

Professor of Sanitary Engineering, University of Washington, Seattle, Wash.

Naturally, all cities located on tidal waters should take advantage of their location in disposing of their sewage and industrial wastes. The exact nature or extent of this advantage, however, is known only in the most general terms and frequently too much or too little dependence is placed on its aid as a substitute for treatment in an orthodox disposal plant. Because so few studies of the capacity of a given tidal estuary to digest sewage have appeared in the technical press, the present discussion is presented for the purpose of describing some of the methods available for analyzing this problem.

From time to time one reads, in engineering reports dealing with the discharge of sewers into tidal estuaries, that a particular tidal prism is so enormous that its oxygen content can readily take care of the sewage to be discharged into it without the production of objectionable conditions in the receiving waters. Although it is recognized that the sewage cannot be mixed throughout the entire tidal prism, the large excess of dissolved oxygen present may give ample assurance that all will be well and that nuisances will not be produced. Presently used studies based on the distribution of *E. coli* are complicated by the variable rates of disappearance of this organism in sea water under varying conditions.

Pollutional Build-Up

Some rough estimates of tidal volumes involved in considering the sewage disposal problem of Seattle, Wash., may be of interest in this connection. Only that part of Puget Sound south of Alki Point, West Seattle, will be considered as it is the tidal prism south of this point that would be involved in oxidizing Seattle's sewage.

This southern portion of Puget Sound has a surface area of 327 sq. mi. Its average diurnal tidal range is approximately 12.0 ft. Therefore, the tidal prism would contain 109,200,000,000 cu. ft. of water flowing past Seattle daily. The tides of long inland estuaries of this sort have peculiarities that are quite different from tides in the open ocean. These peculiarities are illustrated by Figure 1, which shows the tidal variations occurring in Puget Sound. The tides have one long run-in and one long run-out per day. Because of the great irregularity in the tides, for the purpose of the present computations, it is assumed that, from the standpoint of carrying out the sewage, the tidal prism available might be considered as a single tide per day with an over-all range of 12 ft. The short flood and ebb tide following the first high will not greatly influence the total volume of interchange taking place. At the prevailing temperature and chlorinity, the dissolved oxygen content of the water at saturation can be taken as 8.6 p.p.m. The above volume of water would contain, therefore, 58,500,000 lb. of oxygen. Even assuming that 10 per cent of this oxygen had been utilized to take care of the domestic sewage and industrial wastes entering this part of Puget Sound, and assuming also that a residual of 5 p.p.m. of oxygen must be left at all times in the

* Presented at 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949.

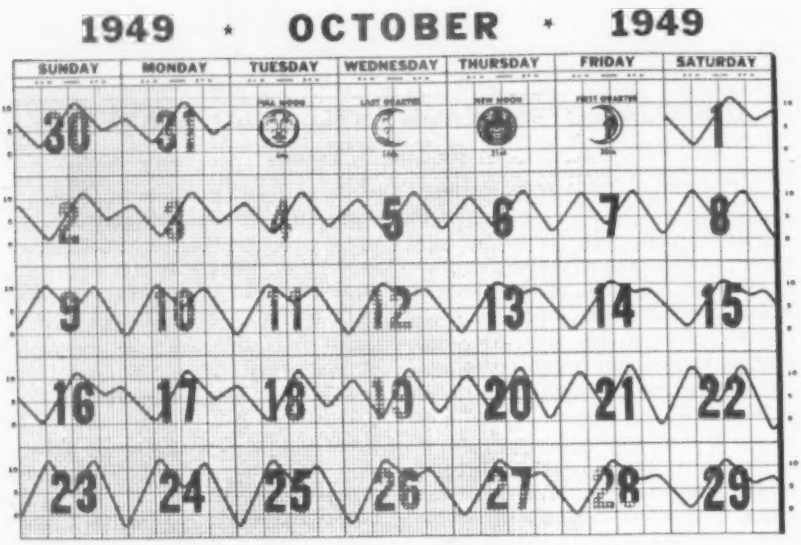

FIGURE 1.—Tidal variations in Puget Sound at Seattle, Wash.

Sound as required by the State Pollution Control Commission, there would still be available 18,600,000 lb. of oxygen, which could theoretically take care of a population of 103,300,000 on the basis of 0.18 lb. B.O.D. per capita. Because metropolitan Seattle has a population of less than 500,000, one might justify an off-hand judgment that with this 200:1 factor of safety, sufficient mixing of the sewage with the Puget Sound water will undoubtedly be produced by tidal currents to secure adequate dilution before the effect of its B.O.D. can make itself felt.

The problem would appear, therefore, to be one of constructing outfalls so as to promote effective dispersion of the sewage throughout Puget Sound waters and prevent local pollutional problems at the outfalls. Proper attention would, of course, be given to chlorination of the sewage and investigations of possible formation of sludge banks at sewer outlets.

It is recognized, of course, that such reasoning greatly oversimplifies the problem. However, to secure the data necessary to determine the resultant pollution in such cases has been laborious and costly. The pollutional build-up that occurs from the shuttling back and forth of sewage in any tidal estuary may be much greater than anticipated. On the other hand, a stratification of the fresh and sea water may produce bottom currents, the existence of which may be unsuspected or its effects difficult to evaluate. Information found in the literature on these problems involved in major harbors is so complex that the present discussion of methods employed in analyzing two less complicated situations, followed by comments concerning a relatively new piece of apparatus for use in such studies, may be of interest.

The least complex mathematical analysis of the magnitude of this pollutional build-up is based on a consideration of the proportion of sewage remaining in the estuary after a single tidal cycle. If this can be determined, the computations involved are simple. Thus, if X is the proportion of the sewage remaining in the estuary or harbor

after one tidal cycle, $X + X^2$ will be the proportion remaining after two cycles, and $X + X^2 + X^3 + \cdots X^n$ will be the proportion remaining after n cycles. However,

$$\sum [X + X^2 + X^3 + \cdots X^n] = \frac{X(1 - X^n)}{1 - X}$$

Because X is always less than 1, X^n rapidly approaches 0 and the right-hand side of the summation equation approaches $X/(1 - X)$ as a maximum. The rapidity of build-up with increasing percentages of sewage remaining in the harbor is shown graphically in Figure 2.

Determination of X

The determination of X for any given case may be difficult. Two methods that have been employed in Pacific Northwest studies will be described briefly.

Model Study

At Alberni, on Vancouver Island, B. C., Tully, *et al.* (1) determined the value of X by the use of a model. Alberni is located at the upper end of a long, narrow inlet, fed by the Somas River and discharging into the Pacific Ocean. A model of the upper end of the inlet was constructed on scales of approximately 1:4,500 horizontal and 1:300 vertical, or a scale ratio of 15:1. The introduction to the report makes the following explanatory statement:

"A distorted model of the head of Alberni Inlet, latitude 49° 15′ N, longitude 124° 50′ W, was constructed in plaster. The independent variables, including the range of the tide, discharge of the river, and the force and direction of the wind, could be controlled independently. The dependent variables of tidal flow and exchange of water, and the vertical and lateral chlorinity gradients, were reproduced to scale.

"The height and phase of the tide, and the wind force and direction were indicated by gauges, and the course of the water movements were traced by a dye solution. . . . Permanent records of the flow were made with moving pictures."

The model was relatively inexpensive but appeared to give satisfactory results. Good checks were obtained between its operation and the water movements, salinity gradients, etc., in the prototype. The authors determined that the tidal build-up or maximum probable pollutional concentration to be anticipated in the inlet would not exceed 85 per cent of the total waste discharge per tide. They believed that the accuracy obtained was well within the limits of observation.

Chlorinity Study

Two reports (2) (3) describe in detail a second method for determining this pollutional build-up, as used by the Washington Pollution Commission (now the Washington Pollution Control Commission) in its study of Grays Harbor. The Commission sought to determine the length of time required

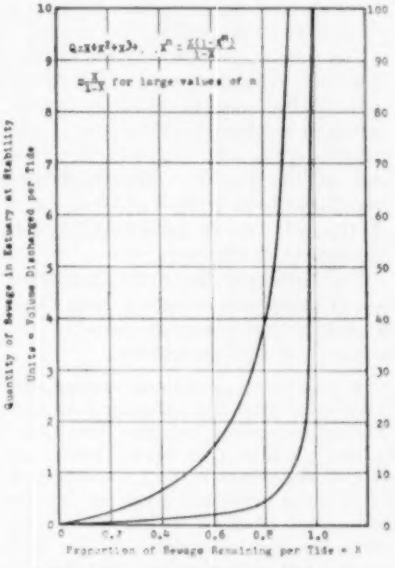

FIGURE 2.—Pollutional build-up in tidal estuaries.

for water from the Chehalis River to pass through the harbor and discharge into the Pacific Ocean with its pollutional load, or to express it differently, the percentage of harbor water replaced per tide by the river water plus water from the Pacific Ocean.

The method employed was to determine the mean chlorinity of the water in the harbor and of the entering river and sea water during a period of low river flow. This is the period of maximum oxygen depletion and occurs during the summer. At this season, the higher fresh-water temperature increases the rate of oxygen demand of the local pollutional load, consisting of domestic sewage and the sulfite waste liquor from a local pulp and paper mill. Figure 3 shows the general geographic features of the harbor and the location of the sampling stations. The higher temperature also decreases the D.O. present in the harbor and river water, while the river's summer flow is at a minimum. Thus, the oxygen demand is at its maximum value at the same time as the oxygen being supplied is at its minimum.

The task of determining the average chlorinity required many determinations. After some preliminary investigation, it was found satisfactory to take samples at the surface, at 15 ft. depth, and at the bottom. Determinations were made both at high and low stages of the tide, at 84 established points throughout the harbor.

The following from the published report gives data obtained from these studies, which occupied parts of the summers of 1937 and 1939:

"During the times when the samples were taken from which the following data were obtained, the rivers emptying into Grays Harbor were at their lowest levels and were discharging at a fairly constant rate. The average estimated discharge for the 1938 period (Aug. 16 to Oct. 6) was 611 second-feet and the average for the 1939 period (Aug. 1 to Sept. 30) was 792 second-feet, the average for the two periods being 709 second-feet.

"From the distribution of chlorinities in the harbor . . . the average chlorinity of the 16,500,000,000 cu. ft. of water in the upper part of the harbor, which is a mixture of various proportions of sea water and fresh water, was computed. At mean low tide, this water occupies that part of the harbor between Station 71 and Station 100 (see Figure 3) and at mean higher high tide, which is about 10 ft. at Port Dock, this water occupies that part of the harbor between Station 30 and a point west of Station 55. The mean chlorinities so determined were 14,020 p.p.m. and 15,560 p.p.m., respectively, and the average of these values, 14,790 p.p.m., will be taken as the average chlorinity of this water. The chlorinity of the sea water entering Grays Harbor was found to be 17,500 p.p.m. on the basis of a number of samples taken at Stations 100 and 101 on incoming tides.

"The periods of observation were purposely chosen to cover times when the river flows were fairly constant. Therefore, to account for the observed average chlorinity of the body of mixed sea water and fresh water maintained during the two-month period of low river flows, 5.46 cu. ft. of sea water $[14{,}790/(17{,}500 - 14{,}790)]$ entered the area with each cubic foot of fresh water. Because the tides follow the moon more closely than the sun and because the lunar day is on the average about 50 min. longer than the solar day, the average duration of one cycle of the tide in places where there are two high waters and two low waters each lunar day is 12.42 hr. During one average flood and ebb of the tide, $12.42 \times 3{,}600 \times 709 = 31{,}700{,}000$ cu. ft. of fresh water entered the upper part of Grays Harbor from the Chehalis River system. In order to maintain the chlorinity of 14,790 p.p.m., $5.46 \times 31{,}700{,}000 = 173{,}000{,}000$ cu. ft. of sea water mixed with the water in the upper part of the harbor. Thus, only . . . about 1.2 per cent of this body of water with its pollutional load was renewed with each cycle of the tide.

"The average time of detention of fresh water in the upper part of Grays Harbor was obtained by dividing the river discharge rate into the total amount of fresh water in that part of the harbor. This average time of detention is about 80 cycles of the tide or about 42 days."

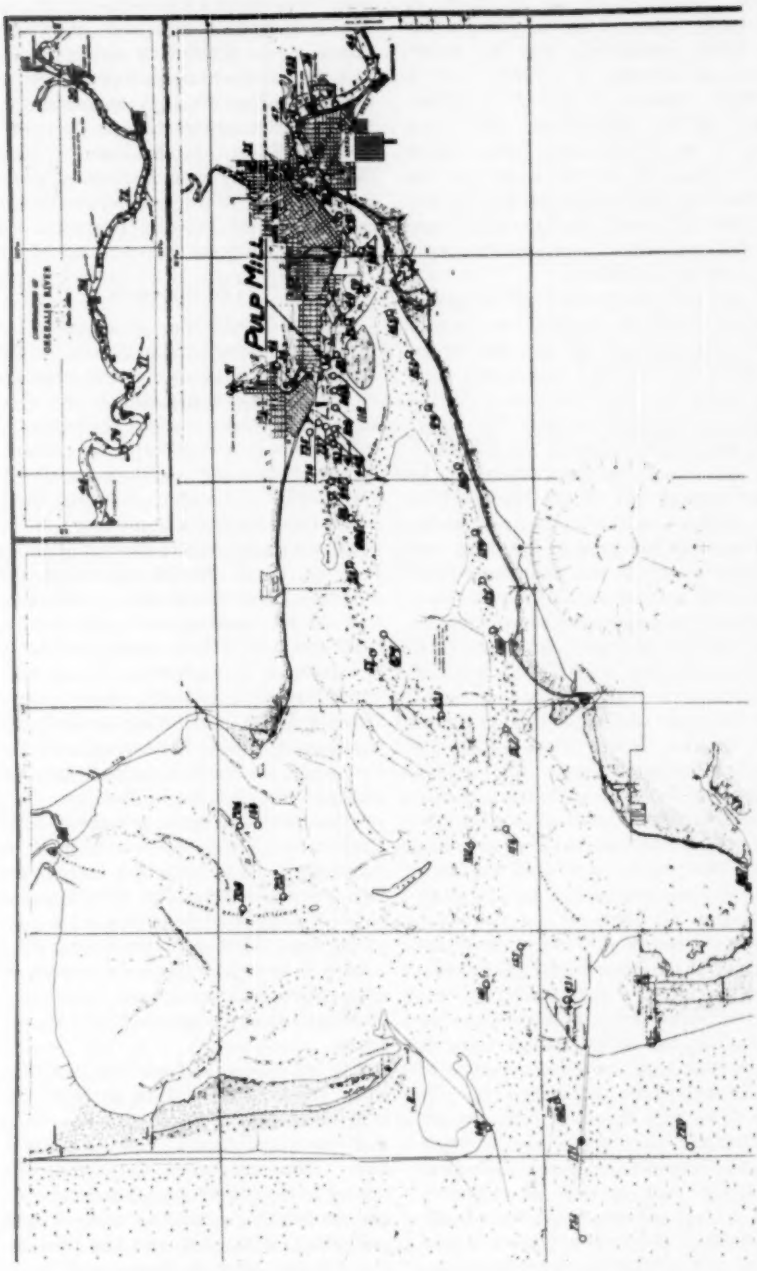

FIGURE 3.—Location of sampling stations in Grays Harbor, Wash.

The concentration of pollution in the water retained in the harbor for the above conditions may be determined as follows: $X = (100 - 1.2)\% = 98.8\%$, whence $X/(1 - X) = 0.988/0.012 = 82.3$. Therefore, the total quantity of sewage and sulfite waste liquor retained at all times in the Harbor was 82.3 times the tidal pollution load (TL) or $12.42/24 = 42.7$ times the daily pollution load, which checks the observed detention.

To get the pollutional load being discharged from the harbor one should add to this the load for one tidal cycle, as the figure of 82.3 times this load represents the load remaining in the harbor permanently = 82.3 TL. One tidal load is therefore to be added to this, making the concentration of the water passing out of the Harbor 83.3 TL. A check on this concentration can be obtained by considering that the 1.2 per cent of the outgoing tidal prism that is exchanged for clean water, times its concentration, equals the tidal pollutional load, TL. Therefore, the concentration = 100 TL/1.2 = 83.3 TL.

In the case of Grays Harbor, however, interest is not centered on its polluting effects upon the Pacific Ocean, but in the conditions existing within the harbor itself where, at Stations 52 and 53, the D.O. approached zero. The report indicates that the water leaving the harbor had its D.O. restored to 80 per cent saturation or better. Although the recuperative capacity of the harbor is not under consideration here, a comparison of this figure with the actual pollution leaving the harbor, as indicated by tests at Station 100, would give a measure of this recuperative capacity, say in terms of oxygen absorbed from the air and through photosynthesis, per acre of harbor area at average tide elevation.

A study such as that described is costly in time and funds, but knowledge gained from the Grays Harbor study should make other similar investigations simpler and less time-consuming. The principal reason for discussing this study in detail is to emphasize the fact that wastes remained in the harbor for more than 40 days, which should point to the importance of the pollutional build-up of tidal basins. Also, the harbor served as a disposal plant that removed 80 per cent of the B.O.D. loading placed on it. However, the fish fared badly in this disposal plant.

STD Indicator

During World War II an improved piece of equipment was developed for making instantaneous determinations of the salinity, temperature, and density of sea water. This apparatus is referred to as a "salinity-temperature-density indicator," or more familiarly as the STD indicator. A recent brief use of this apparatus in making a study of current patterns in Commencement Bay on Puget Sound convinced the author of the usefulness of this new tool in the analysis of pollution in tidal waters. While making a study to determine the capacity of Commencement Bay to handle the sewage from Tacoma, Wash., the author learned that the Oceanographic Laboratories of the University of Washington had recently acquired one of the indicators. Arrangements were made to make several runs through Commencement Bay to determine surface salinities and salinities over various vertical cross-sections located at right angles to the main axis of the bay. This work (including Figures 4, 5, and 6) represents results of research carried out by the University of Washington Oceanographic Laboratories.

The collection of field data for this work required only 3 or 4 days, the computations and plotting of the cross-sections requiring a few additional days. However, more data were obtained in that short time for determining the relative quantities of fresh and salt water in the bay and the prevailing current pattern than could have

been acquired in any other way in much longer time and at much greater expense. From these data some quite unusual flow patterns were found to exist; patterns which had been suspected, but which would have required very many chemical analyses, float observations, and a long, expensive study program to determine.

Figure 4 shows two of the cross-sections, located parallel to each other. That in Figure 4a is about 2,000 feet from the mouth of the Puyallup River; that in Figure 4b, approximately 2,000 ft. farther out in the bay. From these cross-sections, it is apparent that the river water is confined principally to the immediate surface of the bay, although some mixing has occurred to affect the salinities for some distance down from the surface. It is highly probable that the deeper dilution represents mixtures of fresh and salt water returned from Puget Sound by incoming tides, as it would be impossible to mix fresh water to these depths in traveling a distance of 2,000 to 4,000 ft. from the river's outlet. The percentage of river water in these two sections is found to be 1.23 and 1.49 per cent, respectively. The incoming river water is thus confined very largely to the upper foot or so of the bay's depth. This checks results previously determined by sampling. The STD indicator used in this study, however, because of the yaw of the boat from which it was swung, did not give a sufficient refinement in measuring to determine this upper part of the salinity gradient with the desired accuracy. In fact, in determining the surface salinity distribution, the equipment is dragged behind the boat at a depth of approximately 3 ft., although most of the river water with its sewage load is in the upper foot or so of the harbor water.

The sections shown in Figure 4 were taken toward the end of an ebb tide. The salinities, however, show clearly that flow is in the opposite direction

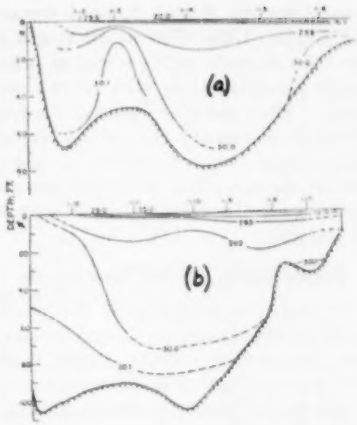

FIGURE 4.—Vertical salinity distribution in two cross-sections; Commencement Bay, December 1, 1948, ebb tide.

to that in which the tide is going, or from the outer to the inner section. It should be noted, for example, that the relative locations of the 30.1-line in the two sections indicate that this heavy water has been forced upward toward the surface of the bay in the inshore sections (Figure 4a) by the decreasing depth of the ridge near the left side of the section. These upwellings of the bottom stratum are easily recognizable by surface turbulence and clear water, and are characteristic of other observations in similar areas. They dramatically show the way in which the heavy water is forced upward by any decrease in cross-sectional area. In this case, the upwelling is caused by the decreased depth of the inner section; but it could be produced also by a narrowing of the channel. Figure 6 also shows the extent of this upwelling (on another ebb tide), which extends along the entire southwesterly side of the bay and swings across the industrial waterfront, as hereinafter discussed.

Depth samples, which had been taken previously for analyzing the water at the bottom of the bay, had convinced the investigators that either the

deeper waters flowed inward toward the mouth of the river at all stages of the tide, or their outflow was at much lower velocities than that of the surface. The sampler always swung strongly in toward the river's mouth after being lowered 100 ft. or more, but as the sampling boat was not anchored only the relative motions could be judged.

Puget Sound Tidal Movements

In order to understand the movement of the water in Commencement Bay, an earlier salinity study made with this equipment at the entrance of Puget Sound from the Strait of Juan de Fuca will be discussed. Figure 5 shows the plan and a sketch of the cross-section along the central axis of Puget Sound at this point, where the water is about 300 ft. shallower than it is farther south. Thus, in effect, a submerged dam extends across the entrance of the sound. On incoming tides, heavy water from the depths of the Pacific, having worked its way up through the strait, flows over the submerged dam into Puget Sound as indicated. This produces a tide rip where the heavy water drags down with it some of the outgoing lighter surface water. Its cause, extent, and detailed behavior have only recently been made clear through the observations of the Oceanographic Laboratories as above noted.

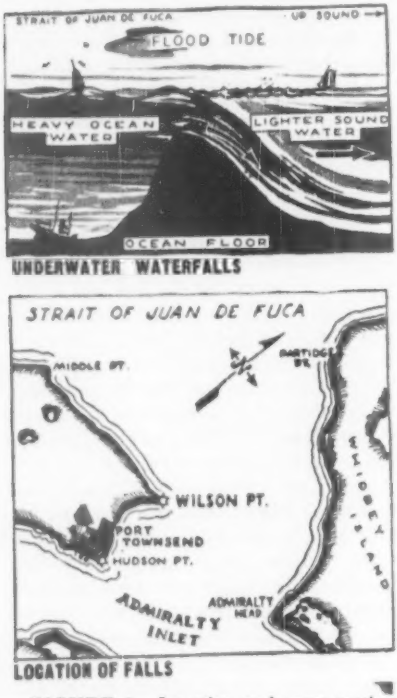

FIGURE 5.—Location and cross-section of underwater waterfalls at entrance to Puget Sound.

This large submarine river of heavy water then flows southward along the bottom of Puget Sound, filling its lower levels, and strikes the projecting southerly shore of Commencement Bay perpendicularly. Here it divides, with part flowing in a westerly direction around Point Defiance and continuing southward. Another part flows easterly along the bottom of the bay, following the city waterfront to the City Waterway, thence northerly, as shown in Figure 6, producing in the bay a counter-clockwise rotation, which tends to keep it flushed out. The Puyallup River is forced toward the northeasterly side of the bay, where it flows out around Brown Point after having been mixed with this submarine stream of heavy water through the welling up of the latter during the outgoing tide. By removing a 12- to 16-ft. layer of water from the surface, the ebb tide encourages this upwelling, which is further aided by its flow along the bay bottom as it turns abruptly upward at its southeasterly end.

The phenomenon of underflow of sea water is a familiar one in rivers emptying into the ocean. In fact, some years ago, after the construction of the Ballard Locks (Seattle) in the Channel connecting Lake Washington with Puget Sound, observations indicated a considerable encroachment of sea water moving along the bottom of

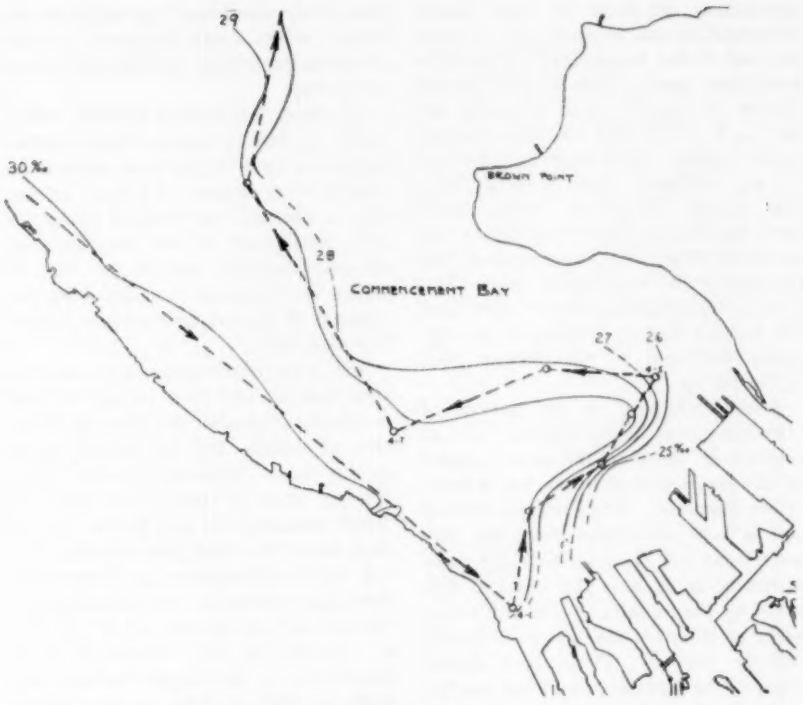

FIGURE 6.—Surface salinities and bottom flow of incoming tide in Commencement Bay.

the channel toward Lake Washington, which it would eventually spoil as a fresh-water lake. To prevent this, a large sump was excavated at the upstream end of the locks, in which the salt water accumulated and from which it was pumped continuously back below the locks. However, information has not appeared in the technical press describing such large submarine movements of sea water as that found to be occurring in Puget Sound.

This phenomenon obviously makes difficult the estimation of the amount of dissolved oxygen furnished by the tidal prism of Puget Sound. It is probable that the heavy water, in forcing the lighter fresh water with its pollutional load to flow off on the surface rather than mixing with a considerable depth of sea water, may tend to flush pollution out of Puget Sound more rapidly than would be the case if the submerged dam at its entrance did not exist. On the other hand, there are insufficient data to indicate to what extent the inflow of this heavy water drags down with it the polluted fresh water, which is headed out to the strait, thus carrying it back into the main body of the sound. This matter undoubtedly can be determined in time with the equipment under discussion.

The matter of principal interest to sanitary engineers is that there is available a new tool for determining movements of mixed fresh and sea water at all depths, and that much useful information can be obtained by its use. Not only can enough data be obtained in a relatively short time so that nearly simultaneous movements

throughout the body of water under investigation can be observed, but also the cost is far below that of methods heretofore used. The Tidal Current Charts of Puget Sound prepared by the U. S. Coast and Geodetic Survey report surface flows only and present a very different flow pattern from that herein described. The charts show the flow to be outward along the southerly shore of Commencement Bay throughout the entire tidal cycle. The data just presented, however, show that the bottom flow is in exactly the opposite direction in the greater part of the bay.

A contour map of the bottom of Commencement Bay (Figure 7) is of interest in showing the scour caused by the movement of heavy water heretofore discussed. The channels scoured out in both directions along the city waterfront are clearly shown by these contours, as is also the channel followed by the combined river and heavy water as it leaves the bay at its northeasterly corner. These give added proof of the flow pattern of the heavier bottom waters of the bay.

In a study made by author in 1944 with reference to the disposal of Tacoma sewage, an observer was placed on the roof of an office building overlooking the bay to observe and sketch the line of demarcation, at ½-hr. periods, between the turbid river water and the clear sea water. We became aware at that time that a tremendous amount of mixing between these two waters was occurring on the outgoing tide. For example, during the first ½ hr. of these observations, although the tide had been running out for 2 hr., the entire river-water front, for a depth of approximately ½ mi., disappeared through vigorous mixing with the sea water from underneath. In the next 1½ hr. the river water moved out toward Puget Sound a distance of about 1½ mi. During the next ½ hr., however, this advance also was completely swallowed up by clear sea water, which could be seen in some places to be welling up from the depths of the bay.

At times, large areas of clear water, 2,000 to 3,000 ft. across, would appear quite suddenly in the area covered by turbid river water. In fact, at one time a channel was cleared along the city waterfront all the way back to the southeasterly end of the bay, as shown in Figure 6, thus following the channel of the submarine river heretofore described.

The most important feature of this stratification and flow pattern is that it greatly decreases the time of detention of sewage and industrial wastes in the bay. Whereas in the Grays Harbor study it was found that the waste remained in the harbor for 42 days under the conditions existing during the investigation, in Commencement Bay the wastes are tremendously diluted and are swept out of the bay in one day or less. Obviously, it is important to investigate bottom currents as well as those on the surface and these have too often been neglected. Although special types of current meters can be used for this purpose, the process is slow and tedious. Such meters should be used, of course, along with the STD indicator, for determining velocities and confirming directions of flow.

The equipment herein discussed is not readily available, as there are in existence only four units. (One at the University of Washington, one each at the Oceanographic Institute at Wood's Hole, Mass., and La Jolla Calif.; and one at Johns Hopkins University.) It is understood, however, that a well-known instrument manufacturing company is willing to build this equipment if as many as 12 are constructed. Probably, no more useful mechanism (the cost of which may approximate $5,000 to $6,000 in addi-

FIGURE 7.—Contour map of bottom of Commencement Bay.

tion to the cost of a boat) could be carried as equipment by large coastal cities, as it would be possible, if desired, to use it to make annual surveys of the pollutional situation adjacent to sewer outfalls so as to determine the efficacy of existing methods of disposal or the need as it developed for additions or modifications thereto.

Acknowledgments

Observations with the STD indicator, including graphs of results, were made by Dr. Thomas G. Thompson, Director of the University of Washington Oceanographic Laboratories, and his assistant, Dr. Clifford A. Barnes, as part of a contract with the U. S. Office of Naval Research.

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DISCUSSION

By Richard H. Gould

Director, Division of Sewage Disposal, Department of Public Works, New York, N. Y.

In general, too little is known of the nature of tidal flows in estuaries that receive polluting wastes and the effect of these flows on the dispersion of these wastes. Professor Tyler has rendered a distinct service in calling attention to underflows resulting from the differing densities of ocean and upland waters. He has called attention to the studies of the Washington Pollution Control Commission in which the salinity of the receiving waters, together with their volume and that of the incoming fresh waters, is used to establish the time of contact of polluting materials in the area under study. His formula appears logical, once the all important element X can be determined. It would be somewhat clearer if this formula were expressed in terms of the days of detention of the daily pollution load, rather than of the daily pollution load as such. The total pollutional load developed in a specific area is, of course, the load that can be developed by the daily contribution over the period of time that the daily contribution remains in the area under study. The total load is by no means a straight-line function with time.

New York City is very conscious of tidal currents and their tremendous importance in the problems of sewage disposal. A few simple examples will point out some of the considerations discussed by Professor Tyler, as they have been found in New York Harbor.

The Hudson River, with an average summer runoff of nearly 7,500 c.f.s., flows through New York Harbor, which finds outlet to the Atlantic Ocean through The Narrows and to Long Island Sound at Throggs Neck. The large areas of the harbor, the Hudson River, and Newark Bay result in large tidal flows. The tidal flow at The Narrows is about 12,000,000,000 cu. ft. The flow of the Hudson River in 6 hr. is only a little over 1 per cent of this amount. Surface currents do not tell the whole story. U. S. Coast and and Geodetic Survey current measurements at The Narrows, for example, show ebb currents running a distance of 9.9 nautical miles, whereas flood currents run only about 4.1 mi. The

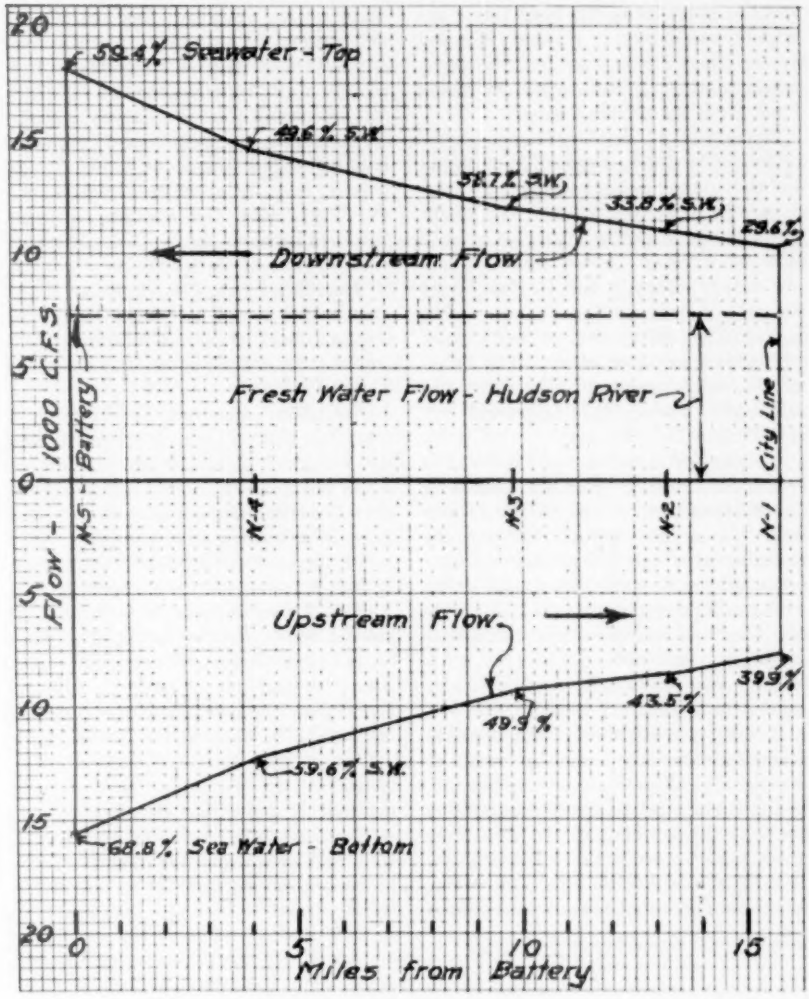

FIGURE 1.

answer, of course, is that there is a heavy underrun of denser sea water that is not apparent from surface floats.

One important local condition is that the tide running up Long Island Sound takes about 3 hr. longer to reach its high at Throggs Neck than it does directly from the ocean at The Narrows. The interference of the two tides creates a tidal range of about 8 ft. in Long Island Sound, as compared with 4.5 ft. in the inner harbor. The 3-hr. lag and the difference in range results in steep hydraulic slopes and heavy currents in the East River.

A relatively small flow of fresh water passes out to Long Island Sound

and the currents in the East River are largely oscillatory. A float released in the East River ran for 3½ days, covered 107 mi., and ended up about 1 mi. from its starting point.

The effect of tidal currents in distributing the load of pollution throughout the harbor is noteworthy. Sewage dosage in New York Harbor was about comparable to that allowed on a good slow sand filter (about 30,000 g.p.d. per acre). That in the Harlem River was about 8 times the average. The Lower East River has a heavy load (100,000 g.p.d. per acre). The effect of the tidal currents is to swap the material around, as indicated by B.O.D. and D.O. values.

The section covered by Figure 1 is the Hudson River from the southerly tip of Manhattan to the northerly city line. It is intended to indicate the magnitude of the interchange of currents of dense water from the ocean with the lighter river water. The City has been recording summer salinities at the top and bottom for more than 40 yr. The Hudson River flow is also a long-term (27 yr.) record.

It will be noted that at the city line there is about 30 per cent sea water at the top and 40 per cent at the bottom. If the fresh Hudson River water flows out with 30 per cent of the total flow of sea water, there is a downstream flow of a little over 10,000 c.f.s. However, to supply the outgoing salt water there must be an upstream flow containing salt water. If this takes place at bottom salinities there is an upstream flow closely approximating that of the Hudson in magnitude. Progressing downstream, the magnitudes of the two countercurrents increase. Actually, of course, flows in opposite directions occur only near the change of tides. Such phenomena have been observed.

By means of these salinity readings, a knowledge of the Hudson River stream flow, and the volumes in the section, times of detention can be computed. That for the section shown is about 11 days.

Particular attention is directed to the fact that, in the section covered by Figure 1, determinations made in 1933, before New York City had gone very far with sewage treatment, showed that D.O. values at the surface were much higher than those at the bottom. It would appear that the upstream current along the bottom is carrying upstream water already depleted of part of its oxygen and possibly carrying also some decomposing organic matter. Such possible considerations make it difficult to be too positive in the application of time and temperature relationships in figuring the oxygen demand of polluting materials.

There are so many variables in most tidal estuaries that great caution must be used in fitting theories to conditions as they exist.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

STANDARD IDENTIFICATION OF PIPING

With the complexity of piping systems found in modern sewage and industrial waste treatment plants the need of some means of readily identifying the contents of such systems is apparent. Not only is there the fact that numerous fires and personal injuries have occurred and much valuable property has been destroyed or damaged because of snap decisions as to pipe contents, but also the further hazard that comes when an emergency requires assistance from an outside agency (for example, a fire department or a police emergency squad) whose personnel are unfamiliar with the plant piping layout. Obviously some simple and universal identification scheme is in order.

Such an identification system for piping is already in use in many industrial plants. The piping identification scheme, developed under the joint sponsorship of the National Safety Council, the American Standards Association, and the American Society of Mechanical Engineers, specifies the use of a general identification plan, and goes on to suggest the possible use of a specific identification plan. It is applicable to all piping systems, but excludes pipes buried in the ground or used as electric conduits.

General Identification

In using the national code, all piping systems in the plant are classified in one of five groups, depending on the nature of the materials carried. Distinctive colors (see Table I) have been assigned to each group so that anyone by simply glancing at a pipe can tell to which classification it belongs. Under the heading of "Fire protection materials and equipment" should be included sprinkler systems as well as other fire protection systems; where a drinking or service water system has special outlets for fire protection, the fire outlets only should be painted red, the remainder being painted green. A dangerous material is always dangerous, despite the fact that in certain special conditions some may logically be called safe. The dangerous classification includes corrosive, flammable, explosive, or poisonous substances. A normally safe material may, however, become dangerous—for example, a water pipe over quicklime. In this case it should be considered safe wherever it is safe, and dangerous only at the locations where it is dangerous.

TABLE I.—Identification of Piping System Contents by Color

Classification		Color
Letter	Description	
F	Fire protection materials and equipment	Red
D	Dangerous materials	Yellow[1]
S	Safe materials	Green[2]
P	Protective materials	Bright blue
V	Extra valuable materials	Deep purple

[1] Or orange.

[2] Or the achromatic colors (white, black, gray, or aluminum).

The color may be applied over the entire length of the pipe, or in color bands 8 to 10 in. wide near valves, fittings, and pumps, and at intervals along the line to insure ready recognition during operation, repairs, and at times of emergency.

Specific Identification

Specific identification of the material in a pipe can be accomplished by a stenciled legend painted on each pipe or by the addition of one or more color stripes. The former method is preferable, with the stencils naming the material carried. If the direction of flow is important, arrows also should be painted on the pipe.

If complete color painting is used for general identification the legends should be stenciled near valves, fittings, and pumps, and at repeated intervals along the line. If color bands are used for identification, the legends should be stenciled directly on the bands. Legends are usually applied with black paint if the background color is light. If the background color is dark, the legend is stenciled on a rectangular portion made light with aluminum paint.

It is important to stencil the legend on the pipe so it is easily visible to workers on the normal floor level. If the pipe can be seen from both sides, the legend should appear on both sides; if near a wall, it may be sufficient to have it only on one side.

Color stripes for specific identification are permitted by the national code, although no recommendations are given concerning selection of colors (legends are preferred). If used, they should be 2 to 4 in. wide. In case of complete color painting for general identification, the stripes should be applied at valves, fittings, and pumps, and at repeated intervals along the line. Where color bands are used for general identification, the color stripes should be applied at the edges of the color bands.

For all identification scheme coloring, whether general or specific, colors should be selected that have the least chemical reaction with prevailing gases or vapors, particularly if moisture is present. Otherwise, the chemical action may cause the pigments to change color, thus defeating the entire purpose of the identification system.

SLUDGE DISPOSAL VS. SLUDGE UTILIZATION *

1949 Operators' Forum

Chairman LeRoy W. Van Kleeck, Principal Sanitary Engineer, State Department of Health, Hartford, Conn.:—Many factors are involved in the question of whether to dispose of sludge or to utilize it. There is even considerable overlap in the two fields of thought if the word "utilization" is interpreted differently—that is, does utilization include production of sludge gas; or does utilization begin only after the treatment plant has completely finished with the sludge? Such questions, however, will be left to the two well-qualified speakers who open the discussion of this subject.

W. Rudolfs, Chairman, Dept. of Sanitation, N. J. Agricultural Experiment Station, Rutgers University:—Some 40 years ago Raymond Wells of Homer, N. Y., wrote a paper on the "Economic Values of Sewage and Sewage Sludge." His thesis was that sewage and sludge

* From transcript of 1949 Operators' Forum, 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949. [One of six subjects discussed; discussions of other subjects have been published in THIS JOURNAL (Feb., 1950, p. 245; Mar., 1950, p. 357; Apr., 1950, p. 561) or will appear in succeeding issues.—Ed.]

should be utilized for their fertilizing values. He felt that the problem of sludge disposition was not impossible, but difficult, requiring the cooperation of chemists, engineers, business men, and politicians. In many respects we are at the same place today. Cooperation and good-will are necessary.

There are, at present, primarily two schools of thought: (1) destroy the filthy mess, and (2) conserve all possible to restore worn out soils and keep food plant production at a high level. The destroyers say that their methods are the cheapest and most hygienic, cause the least difficulties, and prevent nuisances. The conservationists present arguments based on the value of sludge for soil building and stimulation of plant growth. I happen to belong to the conservationists, believing that, particularly for the smaller sewage plants, sludge utilization may be less costly than destruction. After all, utilization of sewage and sewage sludge is fundamental to the earliest methods of disposal (irrigation, sewage farming) and there is nothing that has changed this basic principle. During the years many and varied attempts have been made (composting, sludge digestion, sterilization, etc.) to reduce or prevent nuisances and possible dangers attendant on the utilization of human wastes.

In respect to public health dangers, there seems to be a good deal of misapprehension. Experiments made during the last two years, with vegetables grown in polluted soil and the spraying of *E. coli* cultures and feces on vegetables, show that the organisms are rapidly killed under natural conditions and the numbers of organisms found on growing tomatoes, even sprayed with raw sewage or feces, are at harvest time not greater than those grown in unpolluted soil, provided the spraying was stopped about a month before the tomatoes were picked. It is not a usual practice in this country to apply raw sewage, nightsoil, or raw sludge to the vegetables.

The use of sewage for irrigation, sludge for soil building, and, more recently, industrial use of effluents, is in effect nothing else than what has been practiced for many years. In addition to the use of sludge as fertilizer or fertilizer base, the utilization of gas and recovery of by-products, particularly from unusual or industrial sewages—such as grease and soap (Bradford, England), methyl alcohol and formaldehyde from gas (Johannesburg, South Africa), and alcohol and acetone (Japan)—indicates the possibilities of conservation on a broader scale. However, perusal of these possibilities would lead into longer discussion than is warranted here. Our thesis is: Utilize wherever possible, rather than destroy.

R. W. Rowen, Vice-President, Nichols Engineering and Research Corp., New York, N. Y.:—Obviously, I am biased in favor of heat drying or incineration of sludge as compared with any other methods of disposal. However, this leaning towards incineration is based on a sincere belief that it is the most satisfactory method of sewage sludge disposal. It certainly is the most sanitary, in that the end products are CO_2, H_2O, the nitrogen gases, and inert mineral ash. No other method of sludge treatment converts it to a state where it is absolutely harmless forever more.

Sludge drying or incineration offers some very interesting possibilities that have not been fully exploited, particularly in the simplification of plant operation and design. For example, Milwaukee, Wis., has been incinerating grit and screenings without the addition of sludge for more than 10 years, whereas Detroit, Mich., burns its screenings, grit, and skimmings along with its filtered sludge. This method of handling has eliminated the cost of plant construction and operation, as well as the nuisance, of disposal of

these other end products of sewage treatment. The fuel value contained in grit and screenings is sufficient to evaporate the water present and deodorize the gases. Burning is preferable to burial, and no washing or grinding is necessary.

It should be pointed out that immense simplification and savings in plant design and operation can be accomplished by the elimination of digestion. In many plants, shortage of digestion capacity has been relieved by incineration of vacuum filtered raw sludge to take the overload. In fact, about 70 per cent of all types of sludge incineration plants are handling raw-sludge filter cake.

Few cities incinerate sludge (either as filter cake or from a drying bed) along with garbage and refuse in hand-stoked furnaces. The operation, in general, is quite unsatisfactory, as it is difficult to break up the sludge mass for effective combustion.

An incinerator plant handling both refuse and sludge must be located close to the sewage plant. This is not always desirable from the refuse collection viewpoint, as the sewage treatment plant takes precedence as to location. The flash dryer or multiple-hearth types are finding increasing favor in this service, as they utilize the waste heat from refuse burning to dry the sludge, which is then burned with the refuse.

Another method can be used for combined incineration. The operation consists of grinding garbage and discharging it directly into a multiple-hearth incinerator along with sludge, or, as at Ashland, Ohio, burning ground garbage during the day and sewage sludge at night. Still another plant mixes the ground garbage with the sludge, vacuum filters the combination, and burns the resulting cake.

The third general class of incinerators is that in common use for drying and incinerating sewage sludge alone or in combination with grit and screenings. In the flash-dryer type, the filter cake is mixed with a portion of return dry sludge from the process, dried to about 35 per cent moisture, and discharged to the flash dryer, where it is reduced to about 10 per cent moisture. A part is returned for mixing with the new filter cake, the balance being finished as fertilizer or used as fuel in the furnace.

Another in the same class is the multiple-hearth type, in which drying takes place on the upper hearths and burning on the lower ones. When operated as a dryer, the gas flow in the furnace is reversed (top to bottom) with burning on the top hearth only, to avoid overheating or scorching the material being dried.

Incineration is complete disposal, is unquestionably sanitary, is economical, and is dependable, regardless of weather conditions.

Dr. Rudolfs:—There seems to be considerable misapprehension with respect to the so-called "sanitary" conditions involved in sludge utilization. Putting sludge on land has been considered a somewhat dangerous proposition. However, during the last two years considerable experimental work has been devoted to finding out how dangerous it really is, through the medium of applying to the land raw sludge, digested sludge, horse manure, and artificial fertilizers. Vegetables —specifically, tomatoes and spinach— grown in the supposedly polluted soils show no greater numbers of coliform organisms than do those grown in the artificially fertilized soils. Even after cultures of sewage solids are applied directly to tomatoes, if a few days is allowed before re-testing, the number of coliform organisms is no greater than that ordinarily found on tomatoes as marketed. Fresh feces put on vegetables completely disappeared after 3 days. With the amount of sunlight ordinarily received by the vegetables in the field the danger is very slight.

As to barging sludge to sea; aside from the cost it is a good scheme. It supplies an enormous amount of fish food, both directly and by fertilizing of sea plants. This in turn helps one of the great natural resources of any country, its fishing industry.

W. B. Walraven, Engineer, Springfield (Ill.) Sanitary Dist.:—We have no trouble in getting rid of all the sludge produced from a sanitary district serving about 110,000 people. During the summer private individuals owning two front-end loaders truck the sludge away. They deliver it as much as 12 to 15 miles. Consequently, its disposal costs nothing. Of course, such conditions may not prevail in other communities, but farmers want for their soil the additional humus contained in the digested sludge.

Beginning in 1932, I suggested that the digesting of sewage solids could be made to pay for itself by developing the utilization of sludge gas in gas engines. A crude yardstick set up then still holds good today—2 hp. can be developed per 1,000 population contributing to almost any treatment plant incorporating digestion. Digestion of sewage solids has not only given the farmers of our area an economical humus material, but also has averaged us somewhere between $10,000 and $12,000 annually since 1932 in reduced power costs.

H. E. Orford, Research Engineer, Rutgers University, New Brunswick, N. J.:—In New Brunswick the sludge is vacuum filtered and the list of farmers who want the sludge is long. One area of New Brunswick land needs building up. We have found that the farmers want the sludge because during dry weather they have less trouble with their land drying out than those who do not use sludge.

J. H. L. Giles, State Dept. of Health, Hartford, Conn.:—It would be well for all to go back to the Federation's *Manual of Practice No. 2* on "Utilization of Sewage Sludge as Fertilizer." It seems to have been filed and forgotten. Representatives of the Connecticut Agricultural Experiment Station are agreed that sludge should be returned to the soil, not only at State institutions, but also in all Connecticut communities.

M. J. Stankewich, Erie County Health Dept., Buffalo, N. Y.:—We like to use sludge on the land, especially on golf courses. However, we do experience a lot of trouble with the growing of tomatoes.

G. E. Hubbell, Consulting Engineer, Detroit, Mich.:—In the Detroit area we believe in purification by fire. With the low cost of power in Michigan (less than 1¢ per kw.-hr.) and the requirements of the Michigan Department of Health, is it uneconomical to go into the power business with sludge. Under these conditions the easiest and most economical disposal is to burn the raw sludge.

J. H. Shertzer, City Engineer, Lancaster, Pa.:—Is there any limitation on the percentage of nitrogen humic acid that makes the sludge worthwhile for return to the land?

Dr. Rudolfs:—The sludge is only a fertilizer base and should not be considered a complete fertilizer.

N. M. Fuller, Superintendent, Sewage Treatment Plant, Batavia, N. Y.:—One precaution that should be mentioned is that digested sludges sometimes become thoroughly infected with fungi or root rot. Corn, and sometimes tomatoes, do very poorly with that condition, especially in a damp or wet spring.

Dr. Rudolfs:—If more than 15 tons of sludge per acre is applied to a field, there may be difficulty. Liming once in 4 years is recommended to counteract any acid formation from greases remaining in the sludge. Without the lime, the yield will decrease, despite the building up of the soil.

THE DAILY LOG

Marion, Indiana

By David P. Backmeyer, *Superintendent*

January 6—Three inches of ice on Quarry Lake will permit safe skating. Our chief operator has a cold job today when he climbs to the top of the lighting tower to adjust two of the floodlights for illumination of the skating area (Figure 1). This will please some of our skating enthusiasts, who can't seem to get enough exercise in the daylight hours. The City Recreational Director installs his sound amplification equipment in our sludge filter room, and conveniently mounts the speaker on the ledge of the digester tank wall. We probably have the only singing digestion tank in the country!

January 8—As per the recommendation of the insurance company inspector, the two air storage tanks in the compressor building (one operates at 50 p.s.i. to feed the air relays of the plant meters; the other at 250 p.s.i. for starting the gas engines) will be raised about $\frac{3}{4}$ in. above the concrete supporting foundations. The change is made to forestall the possibility of tank failure caused by corrosion of the tank bottom, resulting from moisture accumulation on the metal surface. This suggestion makes good sense. The change can be made with very little alteration of the connecting piping.

January 9—The pressure-relief safety valve on our gas storage tank (a cylinder of 15,000 cu. ft. capacity at 3 atm. maximum pressure) has not been in working condition for several weeks. Two new valves, one at each end of the tank, will be installed today. Both valves are lever operated and set at maximum pressure of 60 p.s.i. As the gas fuel demand slightly exceeds the gas production today, the tank working pressure can be dropped to zero without wasting any sewage gas. Since examining our valve and finding it worthless, have noticed others at neighboring plants that could hardly be in workable order. Perhaps the safety factor in tank construction has saved our necks on several occasions.

January 12—Equipment insurance inspector at plant to observe internal condition of our 75-hp. gas engine. Have had considerable bearing trouble with this engine. Rod bearings were carefully installed at last servicing

FIGURE 1.

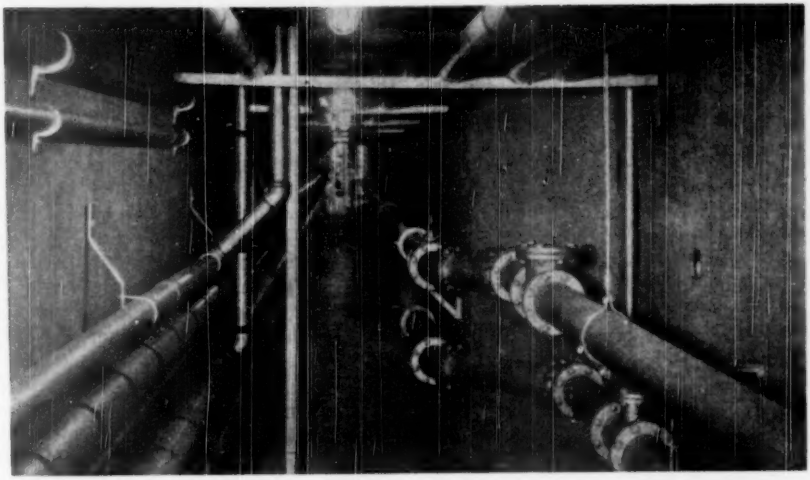

FIGURE 2.—Midway in tunnel between service building and power building, showing sludge-garbage line (upper of two pipes at lower right).

period, using about a 50 per cent closer clearance fit than the normal 0.003 in. for 3-in. crank journal. This recommendation was proven to be a foul ball. We learned an expensive lesson.

January 13—Above-mentioned inspector in office this morning with a sad, sad countenance, indeed. He offers cheerful information that he has found what appears to be a flaw or crack in the engine crankshaft. After making a personal inspection of the web-like crack, a call for help is placed requesting the immediate advice of the inspection department's crack, crack specialist. We soon learn that the services of this expert are much in demand, as he is considered an authority on heavy machinery shaft failures. Upon arrival and subsequent inspection of the shaft, our crack specialist assures us that we have only a surface flaw that probably resulted from slight corrosion of the bearing journal while the engine was out of operation. This certainly was a fooler; after all, a machined part of this kind is hardly adaptable to investigation using such things as files, emery paper, etc.

January 16—The water-jacket safety valve on the No. 3 engine is leaking badly again. We now carry a spare valve that is interchangeable on any one of the three engine water circulation pumps. The leaking valve is sent to the factory immediately for overhaul and re-setting. These valves are manually opened each evening to insure continuous protection to the engine jackets against rupturing pressures.

January 24—Our plant operators have been reporting difficulty in pumping ground garbage from the storage well to the plant digesters. We have a 200-ft. discharge line of 6-in. cast-iron pipe that must be cleaned at intervals of from 4 to 6 months. Today's job is in the hands of the sewer maintenance department crew, who have both the equipment and the know-how for this kind of work. This is a messy job. We certainly wouldn't want any guests in the plant today, as the reeking odor of sour garbage and half-fermented sewage sludge

would not be very pleasant to an uninitiated visitor. The job is done in about 6 hr. and our plant crew soon has the odor problem under control by using H.T.H., strong scrub soap, and plenty of water. If this line were buried in the ground and not accessible for dismantling (see Figure 2) I dread to think what would happen on these clean-out days. A greasy, waxy, solidly matted residue builds up inside the pipe so that the available diameter of the pipe in some places is less than 2 in. The material removed from one 6-in. elbow weighed 4 lb. We have reason to believe most of this is due to garbage, and very little to sewage sludge residues.

February 18—Aeration tank mixed liquor smells like glue and the final settling tanks look milky. This is a repeat performance, and the cause of this mess will not be too difficult to find.

February 19—Visited with the general manager of one of our local milk processing plants for a couple hours this morning. Although the discharge of cheese whey to our sanitary sewers has completely upset our activated plant on several occasions, which incidents always arouse the ire of both the plant management and operation personnel who are charged with the responsibility of maintaining consistent good results in plant operation, we must admit that we have gained a lot of practical knowledge about the milk and related industries while trying to solve our mutual problems. Our associations with plant management have always been pleasant; this particular instance was no exception. We were able to dispose of the plant's surplus cheese whey by pumping it directly to our plant digesters. The whey was hauled to our plant by our tank trucks, normally used for hauling liquid sludge to farm land for disposal (see *Sewage Works Journal*, **20**, 6, 1115; Nov., 1948). The industry agreed to pay all reasonable costs involved in this extra service.

February 23—Spent several hours this evening in the laboratory running determinations for volatile acids on the digestion tank supernatant liquor. Learned another lesson the hard way. Don't expect to get consistent results from this empirical test method when using samples containing appreciable amounts of sludge solids—the test was not intended for examination of sludges.

February 28—At the suggestion of three anaerobic digestion specialists we begin a program of re-circulation of the contents of our primary digester. The discharge of warm liquor to the dome of the tank should help promote the digestion of some of the solids now accumulated in a 50-in. floating scum blanket under the tank floating cover.

March 1—In like a lion—strong wind, snow, and freezing temperatures usher in the month of March.

March 5—Portable pump driven by gasoline engine is installed temporarily for trial run at digester circulation project.

March 6—Results of analysis of samples of top scum reported. Top 6-in. layer contained 33.4 per cent total solids. Sample taken 48 in. down showed 16.4 per cent total solids, and 60 in. down 4.46 per cent solids.

March 18—Supernatant pump from compressor building is moved to service building for permanent installation as digester circulation pump. A special motor to operate the pump at 1,200 r.p.m. will be needed if the pump is to operate efficiently. This pump will deliver 125 g.p.m. and is connected into the piping system so that it can be operated 18 to 20 hr. per day if necessary. And so, the sludge goes round and round!

OPERATION PRACTICES AND EXPERIENCES AT BUTLER, PA.*

By Benjamin S. Johns

Superintendent, Sewage Treatment Plant, Butler, Pa.

The original Butler Sewage Treatment Plant, constructed in 1926–28, consisted of a coarse bar screen; two square primary clarifiers equipped with mechanisms; two rectangular sludge digestion tanks, each of which contained 7 separate hoppers about 13 ft. deep; glass covered sludge beds; and a sludge pump house and small laboratory (see Figure 1). There was no provision for collection of sludge digestion gas, but a boiler and pipe coils were installed to permit some heating of the digestion tanks by burning purchased natural gas. Effluent was discharged to Connoquenessing Creek, which has a very low flow during the warm summer months.

Plant Additions

Primary treatment did not prove adequate and from 1934 to 1939, inclusive, various additions and alterations were made to adapt the plant to chemical coagulation treatment processes. As a result of these changes, a grit chamber and a preaeration tank of approximately 15-min. detention were installed between the bar screen and the primary clarifiers, and two chlorinators were installed in a new chemical storage building. At the same time the corners of the primary tanks were filled in and they were converted to center-feed peripheral overflow units. They were also equipped with home-made skimming devices, which although none too satisfactory, are still in service.

During 1938 and 1939 the city took advantage of P.W.A. and W.P.A. assistance to further expand the plant. Two trickling filters (158-ft. diameter by 8.5-ft. depth), together with a final clarifier equipped with sludge collector, were installed to afford secondary treatment. At the same time a new digester equipped with a floating cover was installed to serve as a primary digester, leaving the old uncovered tanks to serve as secondary digesters.

Provisions were made for utilizing the gas collected from the primary digester to operate an 80-hp. gas engine, direct-connected to a 50-kw. generator. A small compressor and a cylindrical storage tank designed for 50 p.s.i. were provided to collect and store gas produced in excess of the engine requirements, and provisions were made for mixing purchased natural gas with the sludge gas in case sludge gas production was inadequate to meet the engine demands. The electrical layout was such that any or all of the motors could be operated on either gas engine generated power, or power purchased from the local power company, there being individual transfer switches for almost every motor.

Prior to the installation of the trickling filters the flow through the plant had been by gravity, but pumping was necessary to deliver the settled sewage to the filters. These pumps constitute the principal power usage in the plant.

A new modern laboratory and a new mechanically cleaned bar screen and

FIGURE 1.—Original Bradford, Pa., sewage treatment plant, built in 1926.

* Presented at 21st Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 24–26, 1949.

screenings grinder were also installed at that time.

Service Data

The plant serves an estimated population of about 30,000, which includes the City of Butler and a portion of Butler Township. At present, dry weather sewage flow averages about 2 m.g.d. However, flows as low as 1.5 m.g.d. are encountered in extremely dry weather. Although the municipal sewers are supposed to be of the separate type, they receive some roof drainage and many of them are old and subject to excessive infiltration. Sewage flows in excess of 5 m.g.d. have been encountered during wet weather.

All four of the sewage lift stations on the collection system utilize pneumatic ejectors. Three of these stations were constructed in 1926; the fourth, only a few years later. At least one of the stations is now badly overloaded and inadequate during wet weather.

The plant is operated by one superintendent, one laboratory technician, three shift operators, one relief operator, one mechanic, and one laborer. In addition, the force maintains the four pump stations.

Operating Records

Rather extensive operating records are kept. Raw sewage, settled sewage, filter effluent, and final effluent are sampled hourly in proportion to the flow and each 24-hr. composite is analyzed for pH; total, volatile, and mineral suspended solids; and B.O.D. Other daily records include screenings, grit, and sludge volume. Weekly composited samples analyses are made on raw sludge, primary digester sludge transfers to the secondary digester, and secondary digester supernatant returned to the raw sewage. Digested sludge is analyzed as drawn to the drying beds. Each week the primary digester is sampled at four different elevations for temperature, pH, alkalinity, total solids, and volatile solids. Daily readings are made of the meters provided for measuring sewage flows, total gas production, and the distribution of its usage throughout the plant. Daily records are also kept of operating times of the various units, power purchased, power generated, oil used in the engine, cooling water circulated, etc.

Secondary Sludge Return

Piping was so arranged that secondary sludge from the final clarifier could be pumped directly to the digester, to the sludge decanting tank, or back to the raw sewage. However, after a brief trial of the other methods it was found that its return to the raw sewage was most satisfactory. After the trickling filters had been in operation for a year, it was found that they unloaded each spring, and that during that period excessive amounts of worms were deposited in the grit chamber, making the grit very putrefactive and objectionable. This condition has been corrected by changing the piping so that the secondary sludge now goes directly to the primary clarifiers and thus does not pass through the grit chamber or preaeration unit.

Costs

Annual operating costs during recent years average about $39,000. This cost may seem excessive, but there are certain extenuating circumstances that must be borne in mind when making comparisons. First, the costs include the operation and maintenance of the four lift stations, as well as that of the sewage treatment plant proper. Approximately 25 per cent of the mechanic's time is spent in routine inspection and maintenance of the pump stations. In addition, another man is frequently needed for a day or more in making repairs at one or the other of these stations. The troubles most frequently encountered include removing sand and grit deposits in the bucket floats, replacing worn out and

corroded buckets, removing sticks lodged under inlet gates, or removing matches lodged in pilot valves. Formerly, considerable trouble was experienced with wearing and slippage of the flat belts between the motors and air compressors, but with recent overhauling of this equipment and installation of V-belt drives much less trouble results.

As previously pointed out, operating records are quite extensive. Of course, it costs money to keep such records, but it is believed that their value more than justifies their expense. Some plants of approximately the same capacity do not have an operator in 24-hr. attendance. However, cutting down on the hours of attendance would necessitate dispensing with such complete operating records and curtailing operation of the gas-engine generator, thereby increasing the amount of power purchased. To explain why this is the case, it is necessary to describe the sewage pumping facilities in more detail.

Pumping Facilities

Settled sewage may be pumped to the trickling filters by either or both of two constant-speed centrifugal pumps driven by squirrel-cage motors. One of the pumps has a 2.4-m.g.d. capacity and is driven by a 20-hp. motor; the other, of 3.5-m.g.d. capacity, is driven by a 30-hp. motor. Although the power for either of these motors can be supplied by the gas-engine generator, the starting current required is so great that neither pump can be allowed to operate intermittently. Thus whenever the sewage flow is less than the capacity of the pump, either final effluent or filter effluent is returned to the pump well to avoid the intermittent operation that would result if the pumps were controlled by the float switch originally provided. It is necessary for an operator to keep a continual check on the liquor level in the wet well to assure against (a) the pump running dry, or (b) that level becoming so high that settled sewage would back up and discharge directly to the creek without receiving secondary treatment.

Payments to the power company are based on maximum demand and the contract includes a minimum monthly charge of $22.50 (483 kw.-hr.) providing the maximum demand does not exceed 22.5 kw. To keep the maximum demand below this, it is imperative that neither sewage pump be permitted to operate on outside power. Once the demand has been built up, much of the savings resulting from power generations are lost. It is usually possible to avoid such operation during the summer months when gas production is high, but during the winter months gas production is frequently inadequate to meet the engine requirements —and of recent years the auxiliary supply of natural gas has failed. Therefore, it frequently is necessary to utilize purchased power for pumping sewage to the filters during the winter and early spring, despite the fact that sewage flows in excess of 3.5 m.g.d. are by-passed to the creek without secondary treatment at that time. A smaller gas engine, direct-connected to the larger sewage pump, is being installed and it is hoped to utilize the plant's own gas production to better advantage, thereby appreciably reducing the power cost.

Gas Engine

Although the original gas engine is now 9 years old, and has operated about 70,000 hr., it is in just as good condition as ever. Once a year the engine is torn down and overhauled. Usually the only repairs required are the installation of new rings and the grinding of valves. Cylinder liners have been replaced once, and two new cylinder heads have been installed. Oil consumption has always been high, averaging about 1.4 gal. per 1,000 kw.-hr. generated. Originally, the oil was

drained and changed every 500 hr. of operation. After the engine had been in service about 2 years, an oil filter was installed, through which the oil is continuously circulated from the crankcase. Although this unit has not materially reduced oil consumption, it does avoid sludge deposits in the crankcase and the necessity of such frequent shutdowns for oil change. Now the crankcase is drained only once a year, at the time of the annual overhaul.

Other Equipment

Brief mention of some of the maintenance difficulties encountered with other mechanical equipment may be of interest. It has been necessary to change the teeth of the screenings grinder unit every 6 month. Originally, the dull teeth were returned to the factory for sharpening, but in recent years good success has been had in getting them sharpened locally. After being in use for approximately 9 years, the grinder was completely overhauled and new bearings installed.

Considerable difficulty is experienced in maintaining the packings in the two duplex piston sludge pumps, particularly after they have been in use for a few years. The pistons seem to wear out of round. In one of the pumps, installed in 1937, the pistons were replaced in 1947. The other pump was installed two years later, and although its pistons have not been replaced, this must be done soon because it is now almost impossible to prevent leakage around the packing glands.

One of the two rotary distributors on the trickling filters has always operated quite satisfactorily. However, about once a year the other distributor refuses to rotate. In one way or another grit gets into the mercury seal and this is believed to cause the trouble. Withdrawing, cleaning, and replacing the mercury seems to remedy the difficulty for approximately another year.

Chlorination

Chlorine is purchased in ton containers. About one carload a year is used, although prior to the installation of the trickling filters about three times as much was used. Originally, the plant water supply was obtained from a shallow well. About four years ago, when that supply failed completely, a small screen chamber was installed in which final effluent is passed through two very fine-mesh copper screens in series. This screened effluent was the only water supply, other than drinking water carried by the operators, and for three years it was used to operate the chlorinators, for all hosing and washing purposes, and to supply the distilled water apparatus in the laboratory. This year the city was finally able to prevail upon the local water company to lay a service line to the plant. However, the use of screened effluent in the chlorinators has proven so satisfactory that its use for that purpose is being continued, thus effecting a material saving in water bills.

Sludge Problems

The chief operating difficulty at the plant has been with the disposal of digested sludge and supernatant liquor from the secondary digesters. The original glass-covered sludge beds constructed in 1926–28 have an area of 12,960 sq. ft., or about 0.43 sq. ft. per capita. No additional drying beds were provided when the plant was expanded to provide complete treatment. Although the beds were more than adequate to handle the digested sludge when only primary treatment was used, they have proven entirely inadequate for the larger amounts of sludge resulting from complete biological treatment.

Normally, digestion progresses so actively in the primary digester that there is little or no variation in solid or volatile content of the sludge from top to bottom of that tank. Therefore, no sludge is drawn from that tank to

the drying beds, all withdrawals being transferred to the secondary digesters. If space is available in the secondary tanks, the sludge concentrates there to 5 to 7 per cent solids, leaving a very clear supernatant containing less than 0.2 per cent total solids. This can be returned to the raw sewage with no difficulty whatsoever. However, during the winter and early spring, sufficient sludge cannot be dried on the beds to keep the level down in the secondary digesters. The sludge builds up and, of course, overflows as supernatant back to the raw sewage. At such times this so-called supernatant may contain from 2 to 5 per cent total solids, which settle out in the primary clarifiers, increasing the amount of sludge to be introduced into the new digester, hence the amount of sludge to be transferred to the secondary digesters, and hence a further increase in the volume of poor supernatant going back to the raw sewage.

Although no increase in B.O.D. of final plant effluent has been detectable as a result of this poor supernatant, it has been found that it not only reduces the total amount of gas, but actually reduces the amount of gas collected per pound of volatile matter added to the primary digester. Of course, this reduces the amount of gas available for engine operation and hence increases power costs.

FIGURE 2.—Original glass-covered sludge beds are supplemented by new underdrained open beds and new undrained auxiliary drying bed (left).

The poor supernatant was lagooned for a number of years, but eventually the lagoon became filled and, even though its use was discontinued throughout the entire summer of 1947, it was found practically impossible to get excavating equipment in to clean it out. In the spring of 1948 four open, underdrained sludge beds (Figure 2) having a total area of 14,300 sq. ft. were added, together with an additional area of about 16,000 sq. ft. covered with cinders but without underdrains. With this increase in sludge drying facilities, it is expected that the troubles with poor supernatant will be at an end.

TIPS AND QUIPS

Public Employee Safety

Public employee safety is "a problem in economy, efficiency, and public service" according to a pamphlet recently distributed by the National Safety Council. The leaflet gives examples to show that safety programs by public employers can cut tax funds spent for employee compensation and medical costs by more than the cost of the program, improve employees' attitudes and increase their working efficiency, and raise public esteem. Figures cited show that city employment is the fourth most hazardous occupation in a list of 40 major industries compiled by the Council.

The secret of increased safety lies in planned and organized safety work. Foremost among the items that are worthwhile in stopping accidents are: records to determine the most prevalent and most serious accident causes, continuous inspection to reveal unsafe conditions and practices before they cause injury, correction of unsafe con-

ditions by surrounding every job with safeguards for both workers and the public, training of supervisory personnel in safety matters, employee job training to obviate dangerous performance and usage of equipment, and maintenance of active safety consciousness and interest on the part of the individual employee.

As a part of its program of furthering safety wherever unsafe conditions are found, the Council has established a Public Employee Safety Committee. Basic in its considerations is the attitude that "For the public money spent because of accidents which have already happened, the public gets less than nothing. For the money spent for the prevention of accidents, the public gets the fullest possible return."

Like charity, safety begins at home. It ranks well up on the list of things that should be attended to personally and not left for the other fellow to do.

Fire Extinguisher Decals

To help identify and locate the proper fire extinguisher in a hurry, a decalcomania manufacturer reports the development of three unusual new decal sets for positive selection of three types of extinguishers for fires of: (1) wood, paper, and rubbish; (2) electric, gas, and chemical; and (3) any origin except electrical. A large decal (8 by 9 in.) is supplied for application to the wall above the fire extinguisher, and a smaller one ($1^3/_4$ by 2 in.) for the extinguisher itself. The new decals identify in three ways: by color code, by design, and by printed instructions naming proper use.

The decal selection sign for fires of wood, paper, or rubbish origin has black and yellow diagonal bars. For electric, chemical, or gas fires, the identifying design has red and white horizontal bars. The third decal identifies foam-type fire extinguishers, which are suitable for any but electrical fires; it employs red and white horizontal bars cut diagonally by a combination yellow and black stripe. It is claimed that reports indicate a reduced time lapse in selecting the right fire extinguisher when the decals are used, especially when employees have color deficiencies or are unable to read.

Alaskan Report

For any who may have had bad winter experiences with their sewers, we offer the comforting thought that there's always someone whose troubles are worse than our own. Perhaps even the worst sufferers will be able to spare a little sympathy for those charged with maintenance of sewers in Fairbanks, Alaska, whose problems are summed up in a letter from G. H. Dunstan, engineer for the Alaska Health and Sanitation Activities, U. S. Public Health Service, published in a recent issue of the "Official Bulletin," Alabama Water and Sewage Association. Says Mr. Dunstan:

"Some ten years or more ago a P.W.A. project installed sanitary sewers in the city. The design was apparently done by men who were not familiar with sanitary engineering, and is peculiar in many respects. Perhaps the most serious defect is the use of grades very much flatter than those recommended. All main sewers are made of wood-stave pipe. The city does not like even metal house connections. Since the sewers often freeze up in winter, it is necessary to thaw them out. For this purpose portable boilers on skids are dragged around, and steam is run into the pipes. The wood pipes seem to withstand this operation with less damage than metal pipes.

This past summer (1949) the worst sections of sewers were uncovered. In some cases they had to be cleaned. House connections, which had been abandoned or had holes cut into them

in the early years of operation when they froze, had not been properly plugged, with the result that much dirt had gotten into the lines. In some places settlement had resulted in negative grades. Some of this may have been due to the melting of the permafrost. Where such settlement was found, the pipes were taken up and replaced. In some cases, sawdust and tarred paper were placed in the trench with the idea of serving as insulation. Thermocouple installations may give some information as to their value.

Other questions that are being raised deal with septic tanks, tile disposal fields, and the operation of sewage treatment methods. How are these affected by the extreme cold weather? In time, it is hoped that all of these problems can be studied."

New Chlorine Reference Book

A new "Chlorine Handbook," prepared specifically to help meet the greatly increased and still growing demands for basic data covering the safe storage, handling, and use of chlorine, as well as its physical properties, has just been completed by Diamond Alkali Company, Cleveland, Ohio. The 44-page, file-size, quick-reference technical manual, which is liberally illustrated with graphic charts, drawings, tables, and pictures, holds particular interest for works managers, superintendents, and other plant executives responsible for storing, handling, and using chlorine with maximum margins of safety to personnel, plant, and equipment.

The booklet describes and illustrates the three approved standard-size cylindrical containers used to package liquid chlorine for rail or truck shipment; gives "how-to-do-it" data on proper chlorine service tools, equipment, and accessories; shows typical installations; and presents similarly helpful information on first aid measures, gas masks, and emergencies. The second section of the handbook is devoted entirely to a comprehensive yet concise review of the major physical properties of chlorine. Supplementing this part of the discussion are 8 charts and tables.

Copies of the handbook may be obtained by letterhead request to Diamond Alkali Company, 300 Union Commerce Building, Cleveland 14, Ohio.

Waste Heat Recovery

Although recovery of waste heat in sewage treatment plants is not new, a method used in one industrial plant may prove of interest to plant personnel concerned with such installations or their adaptation. In the plant described in a bulletin of the Compressed Air and Gas Institute, three 315-c.f.m. air compressors, two driven by diesels and the third by a spark-ignition engine using manufactured gas fuel, deliver 400,000 B.t.u. per hr. into a system suitable for space or process heating.

The arrangement for utilizing recovered waste heat is shown in Figure 1. The heated water is taken directly

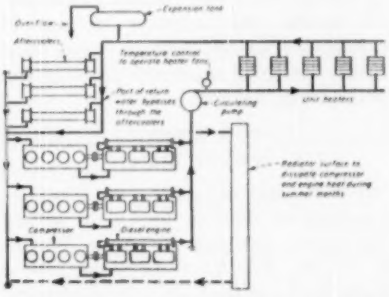

FIGURE 1.—Heat-recovery hook-up for utilization of waste heat in air compressor-engine installation.

from the discharge of the engine-compressor cooling system and circulated by the engine pump through the heating equipment. Controls are provided in the hook-up to keep the unit-heater fans from operating until the water reaches a pre-set minimum tempera-

ture. This prevents blowing cold air. For heat dissipation in the summer months, the water is circulated as for winter operation, but the unit-heater fans are reversed to discharge outside the building.

The cost of equipment and piping necessary to recover waste heat is relatively small and the scheme results in real dollar savings. In the scheme described, heat recovery is 1,250 B.t.u. per hr. per cu. ft. per min. of compressor capacity at 100 p.s.i.

Band-Aid Pipe Labels

Application of the recommended piping identification code of the National Safety Council (see page 699) is made much simpler by a set of adhesive pipe identification labels recently placed on the market. The labels, of the "legend" type for pipe content identification, are printed on an adhesive cloth tape for permanence and ease of application. Several sizes of standard stencil lettering are available in a wide variety of legends for materials commonly piped in treatment, as well as industrial, plants. To apply the labels, the adhesive surface is stripped from a backing card and simply wrapped around the pipe in the desired location.

Welfare State?

What seems to be a pretty good description of modern trends in urban community life was given by Wayne A. Kivell, The Dorr Company, New York, N. Y., at the 21st Annual Conference of the Pennsylvania Sewage and Industrial Wastes Assn., held at State College, Pa., Aug. 24–26, 1949. In connection with his discussion of high-rate filter loadings, Mr. Kivell said:

"A trickling filter is a modern housing development—a "bug" house for Bronx Zoos in miniature. There are millions of tiny apartments, formed by the interstices between the stones, all occupied by biological zoos of living organisms requiring much the same accommodations as human beings—shelter, air, heat, food, water, and with some forms, light. These colonies would thrive best if the apartments were air-conditioned, heated to incubator temperatures, and supplied with warm water. Unfortunately for our tenants, we are not yet able to provide ultramodern apartments, nor are we able at all times to supply food that will conform to the development's pure food and drug act. Consequently, because of poor ventilation, lack of heat, cold water, and unwholesome food, our tenants are subject to ills and epidemics that reduce the population and, therefore, the demand for B.O.D. food. However, given livable conditions and a near-constant supply of wholesome food, the filter tenants will increase in proportion to the food supply, with the result that the "left over" B.O.D. food in the effluent will analyze and measure much the same regardless of the loading per acre foot—up to a point of overcrowding. The food, too, must be served continuously and not in meals as we once did.

On this premise, it may be surmized that peak loads of B.O.D. food are partly wasted to the effluent because filter tenants are unable to expand their populations quick enough to utilize it or sufficiently increase their own normal intake to absorb the excess. The use of storage tanks and the averaging of sewage flows by recirculation will be of measurable assistance in leveling the rate of food supply, and, therefore, the wastage to the effluent."

What a life! Nothing to do but eat, drink, and be gay—and raise kids. Even a little "happy water" (product of fermentation) is supplied now and then by a paternalistic overseer. Of course, there will always be some tenants who are disgruntled because no car is furnished!

Proceedings of Member Associations

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

21st Annual Meeting

Dickinson, North Dakota, October 6–7, 1949

The 21st Annual Convention of the North Dakota Water and Sewage Works Conference was held at Dickinson, N. Dak., on October 6–7, 1949. Total registration was 113.

At the technical sessions of the meeting, papers of interest to those in the sewage works field were:

"Better Joints for Clay Pipe Sewers," by H. J. Rosenthal, District Engineer, Clay Products Assn.; and

"The Human Factor in Municipal Administration," by LeRoy Harlow, City Manager, Fargo.

At the Annual Banquet, Mark D. Hollis, Asst. Surgeon General of the U. S., spoke on "Environmental Sanitation."

Separate forums were held on the morning of October 7 for sewage works and water works operators to discuss their problems. At the business luncheon held immediately thereafter, the following officers for 1949–50 were elected:

President: A. F. Hulteng, Grand Forks.
Vice-President: H. H. Behlmer, Fargo.
Secretary-Treasurer: Jerome H. Svore, Bismarck.

Following adjournment, the convention delegates enjoyed a guided tour of the Dickinson water and sewage plants and the Dickinson Dam, under construction by the U. S. Bureau of Reclamation for irrigation, water supply, and river control purposes on the Heart River.

JEROME H. SVORE,
Secretary-Treasurer

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Fifteenth Annual Meeting

Rapid City, South Dakota, September 28–30, 1949

The Fifteenth Annual Meeting of the South Dakota Water and Sewage Works Conference, held in Rapid City, September 28 to 30, 1949, was well attended. The programs were highlighted by several illustrated talks on sanitary developments in Japan, presented by J. J. Hinman, Jr., who spent some time with the U. S. Army of Occupation.

Officers elected for the year 1949–50 were:

President: C. B. Madison, Winner.
Vice-President: Wallace Johnson, Huron.
Secretary-Treasurer: Charles E. Carl, Pierre.

Following adjournment of the business meeting, held in conjunction with the Conference Luncheon on the last day, association members enjoyed an inspection trip to the new Rapid City sanitary landfill, and the sewage and water treatment plants.

CHARLES E. CARL,
Secretary-Treasurer

NORTH CAROLINA SEWAGE WORKS ASSOCIATION

21st Annual Conference

Southern Pines, North Carolina, November 7–9, 1949

The 21st Annual Meeting of the North Carolina Sewage Works Association was held at Southern Pines, N. C., on November 7–9, 1949, in conjunction with the 29th Annual Conference of the North Carolina Section, AWWA. Total registration for the joint meeting was 226.

At the morning session on November 7, papers were presented as follows:

"Experiences in Extending City Limits," by George C. Moore, Dept. of Utilities, Albemarle.

"Water Supply and Sewage Disposal—Today and Tomorrow," by L. H. Enslow, Editor, *Water and Sewage Works*, New York City.

The afternoon session was devoted to three discussion panels on water works, sewage works, and general subjects, respectively. Subjects discussed by the sewage works panel included sewer maintenance and inspection, treatment plant maintenance, small-plant operational problems, and sewage treatment financing. Discussion at the general session centered on safety practices in plant operation, records for small plants, and rates for special services.

November 8 was devoted to water works papers, with the exception of a paper by C. E. Perkins, City Manager, Winston-Salem, N. C., on "Water and Sewage Practices in Europe."

At the concluding session, on the morning of November 9, papers were presented as follows:

"Industrial Use of Streams—A Second Look," by L. L. Hedgepeth, American Cyanimid Co., Bound Brook, N. J.

"Federal Activities in Stream Pollution Abatement," by Lewis A. Young, Div. of Water Pollution Control, U.S.P.H.S., Atlanta, Ga.

"Studies of Increased Air Application in Sewage Treatment," by W. G. Brown, Water and Sewer Dept., Durham, N. C.

At the business session on November 8, the Association amended its constitution and by-laws to permit an increase in dues to $6.50 annually in accordance with the Federation's new dues schedule. Officers elected for 1949–50 were:

Chairman: E. R. Tull, Rockingham.
Vice-Chairman: W. W. Atkins, Asheboro.
Secretary-Treasurer: E. C. Hubbard, Raleigh.

E. C. Hubbard,
Secretary-Treasurer

OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTES CONFERENCE

23rd Annual Meeting

Stillwater, Oklahoma, November 28–December 1, 1949

A record 170 participants attended the 23rd Short Course of the Oklahoma Water, Sewage and Industrial Wastes Conference, held at Oklahoma A. & M. College, Stillwater, November 28–December 1, 1949. This second session during 1949 saw several city managers and city engineers take the complete course with their superintendents and operators.

Lectures and panel discussions, supplemented by laboratory sessions, comprised the technical program. Topics covered in the sewage works

courses included sewer maintenance, pumps and lift stations, sewage characteristics, sewage treatment, sludge digestion and disposal, and equipment operation and maintenance.

Of general interest to all were the papers "The National Stream Pollution Problem," by H. W. Poston, U.S.P.H.S., Little Rock, Ark., and three evening sessions on "Public Relations for Water and Sewage Works Departments," by M. L. Powers, Director, Division of Engineering and Industrial Extension, Oklahoma A. & M. College.

As heretofore, the highlight of the Conference was the Annual Dinner, held Wednesday evening, November 30. The guest speaker, F. M. Dawson, Dean of Engineering, University of Iowa, spoke on "Planning a Uniform Plumbing Code." At the business meeting immediately following, the name of the Conference was changed to include the words "industrial wastes."

Officers elected for the year 1950 were:

President: Grover L. Morris, Oklahoma City.
Vice-President: R. B. Riddle, Frederick.
Secretary-Treasurer: H. J. Darcey, Oklahoma City.
FSWA Director: J. T. Sprague, Miami.

H. J. Darcey,
Secretary-Treasurer

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

22nd Annual Meeting

New York, N. Y., January 20–21, 1950

The 1950 Annual Meeting of the New York Sewage and Industrial Wastes Association was held at the Statler Hotel in New York City on January 20–21, 1950. A total of 396 members and guests were registered.

At the business session, with President Paul Bardet presiding, members unanimously approved a change in name of the association from "New York State Sewage Works Association" to "New York Sewage and Industrial Wastes Association." Also, the following officers were elected:

President: J. W. Johnson, Buffalo.
Vice-President: J. M. MacCrea, Syracuse.
Treasurer: J. C. Brigham, Albany.
Secretary: R. C. Sweeney, Rochester.

The morning technical session was opened with the paper, "Rational Design Criteria for Sewage Absorption Field" by John E. Kiker, professor of public health engineering, University of Florida. "Resume of Progress and Activities Under the N. Y. State Water Pollution Control Act," was presented next by A. F. Dappert, secretary, Water Pollution Control Board, N. Y. State Dept. of Health.

At the luncheon meeting, Daniel A. Okun, New York City, was presented with the association's Kenneth Allen Award for his paper "A System of Bio-precipitation of Organic Matter from Sewage," published in the September, 1949, issue of *Sewage Works Journal*. Speakers at the luncheon included W. H. Wisely, FSWA Executive Secretary, who spoke on Federation affairs, and Sol Pincus, New York City, formerly chief of the Environmental Sanitation Section, World Health Organization, at Geneva, who

spoke on "World Health Organization and Sanitary Engineering."

The afternoon program included a paper by R. H. Gould, director, Division of Sewage Disposal, N. Y. City Dept. of Public Works, "Recent Structural Changes in the Wards Island Plant for Increasing Capacity and Improving Operation." Also on the afternoon program was a panel discussion on the subject "Industrial Waste Disposal in Relation to Municipal Sewage Treatment." The panel was led by G. E. Symons, associate editor, *Water and Sewage Works*, New York City.

The technical program was completed on the morning of January 21 with an inspection of New York City's Wards Island sewage treatment works.

R. C. SWEENEY,
Secretary

VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

4th Annual Meeting

Winchester, Va., March 30–31, 1950

The Virginia Industrial Wastes and Sewage Works Association 4th Annual Meeting was held at Winchester, Va., March 30–31, 1950, with headquarters at the George Washington Hotel. A total of 160 registered for the meeting.

At the business session, held on the morning of March 30, the following officers were elected for the coming year.

President: J. A. Rives, Blacksburg.

Vice-President: J. N. Millar, Elkton.

Secretary-Treasurer: W. L. Scott, Richmond.

The technical program was begun with a paper by Robert S. Phillips, superintendent of sewage treatment, Charlotte, N. C., entitled, "Disposal of Industrial Wastes in Municipal Sewer Systems." "Experience with Industrial Wastes at Winchester," by S. H. Reaves, superintendent of water and sewerage, Winchester, followed. Richard Messer, director, Div. of Engineering, State Dept. of Health, then presented a paper on "Review of Progress in Sanitary Sewage Disposal in Virginia."

The afternoon of March 30 was devoted to an inspection trip of the Winchester sewage treatment plant.

The Annual Dinner was held in the Ball Room of the George Washington Hotel, with entertainment following for the remainder of the evening.

The March 31 session featured the following papers:

"Some Problems of Fly Ash Disposal," by Harold L. Jacobs, E. I. du Pont de Nemours & Co., Wilmington, Del.

"Biological Tests of Treated Waters," by Charles E. Renn, associate professor of sanitary engineering, Johns Hopkins University, Baltimore, Md.

Highlight of this day's session was the trip to the American Viscose Corp. plant at Front Royal. Following luncheon at the plant, B. N. Scheuer and C. W. Joseph, chemical engineers, American Viscose Corp., presented "Industrial Waste and Sewage Treatment at the American Viscose Corp., Front Royal, Va." The remainder of the afternoon was spent in inspection tours of the plant.

W. L. SCOTT,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Michigan Sewage Works Association	Park Place Hotel, Traverse City, Mich.	May 22–24, 1950
New England Sewage Works Association	Hotel Sheraton, Worcester, Mass.	June 1, 1950
Alabama Water and Sewage Association	Alabama Polytechnic Institute, Auburn, Ala.	June 7–9, 1950
Central States Sewage Works Association	Indianapolis, Ind.	June 9–10, 1950
New York Sewage and Industrial Wastes Association (Spring Meeting)	Hotel Jamestown, Jamestown, N. Y.	June 12–13, 1950
Institute of Sewage Purification	Bournemouth, England	June 19–23, 1950
Ohio Sewage and Industrial Wastes Treatment Conference	Gibson Hotel, Cincinnati, Ohio	June 28–30, 1950
Pennsylvania Sewage and Industrial Wastes Association	Pennsylvania State College, State College, Pa.	Aug. 23–25, 1950
West Virginia Sewage and Industrial Wastes Association	Hotel Pritchard, Huntington, W. Va.	Sept. 14–15, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Georgia Water and Sewage Association	Ga. Institute of Technology, Atlanta, Ga.	Sept. 20–22, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
Federation of Sewage Works Associations	**Hotel Statler, Washington, D. C.**	**Oct. 9–12, 1950**
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950

Reviews and Abstracts*

A Survey of the Liquor Disposal Problem. By E. H. M. Badger. *Gas World* (London), **130**, 2038 (Dec. 24, 1949).

The harmful effects of gas liquor through direct toxicity and reduction of dissolved oxygen in streams are outlined. The B.O.D. test is not wholly satisfactory, and caution is urged when applying it to trade wastes. It is recommended that ammonia be distilled, and the spent liquor be discharged to municipal sewage plants for biochemical oxidation. The Royal Commission on Sewage Disposal suggests that sewage effluents contain a maximum B.O.D. of 20 p.p.m. Discharge of 0.25 per cent of crude, or 0.5 per cent of spent, liquor to the sewage would permit this standard to be met, but 0.5 per cent of crude liquor would not. Tests showed that phenol and catechol are oxidized easily, but some polyhydric phenols are not.

A new treatment process shows some promise. Benzol washing removes 80 to 95 per cent of phenol; the washed liquor is distilled and the spent liquor concentrated in triple-effect evaporators to yield a 20 per cent solution of ammonium chloride; the concentrate is washed with phenosolvan to remove polyhydric phenols and ammonium chloride is crystallized from the washed liquor. Thiocyanates and thiosulfates are concentrated in the mother liquor. It is passed through a basic anion exchanger, which can be regenerated with alkali; the small bulk of regenerant can easily be disposed of. This treatment improves the quality and color of the spent liquor, but its cost has not been established.

Discussion. *Gas World*, **130**, 2078 (Dec. 31, 1949).

Crude liquor was said to be unsuitable for discharge to sewers because of its high sulfide and cyanide content; it may also cause sewer blockage near the point of discharge because of foam generation. No conclusion has been reached on computation of a proper charge for treating gas liquor with sewage, but the Townsend formula has been suggested. Under this formula the charge would be $1 + \frac{S}{60} + \frac{M}{75}$ = pence per 1,000 gal. of trade effluent, where S represents the suspended solids in parts per 100,000, and M is the McGowan strength after 2 hr. quiescent settling. The McGowan strength is 6.5 times the oxygen absorbed from N/8 permanganate in 4 hr. at 26.7° C., in parts per 100,000, plus 4.5 times the nitrogen, in parts per 100,000. Experiments showed that 1.4 would be a better value than 6.5 because some substances in gas liquor are rapidly oxidized by permanganate. The 4.5 factor was questioned, especially where little of the nitrogen would be oxidized, but there were no data on which to base a change.

The comment was made that by the oxygen absorbed test, gas liquor is 100 to 200 times as strong as sewage; by the B.O.D. test, 20 to 30 times; and by nitrogen content, 200 to 400 times. It was recommended that the research started by the Institute of Gas Engineers be continued and expanded to include the effects of various gas liquor constituents on sewage purification.

It was suggested that gas liquor could be improved by eliminating the recirculating liquor; but this would mean separate disposal of that liquor. The effects of gas liquor could be reduced by electro-detarring, but the recirculating liquor must be disposed of separately to obtain the full effect of this treatment. The newer solvents (for example, butyl acetate) were proposed to remove polyhydric phenols from the liquor.

Richard D. Hoak

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Water Pollution Legislation. ANON. *Chemical Age* (London), **61**, 835 (Dec. 17, 1949).

A Ministry of Health Commission has recommended passage of a new Act to control pollution, instead of amending the Rivers Pollution Act of 1876. The proposed Act would confer rather wide powers on River Boards to frame by-laws. The proposal states that River Boards "should be able to prescribe standards with which effluents discharged into a stream or part of a stream must comply; effluents which do not comply with a standard should be deemed to be offensive or injurious." The standards should be prescribed by by-laws subject to confirmation by the Minister of Health, but such a by-law should not be confirmed "until a proper survey of the stream or part of a stream has been completed." River Boards should be allowed to take proceedings, without consent of the Minister of Health, wherever an effluent does not meet a standard.

RICHARD D. HOAK

The Present Status of Plating Room Waste Disposal. BY C. F. GURNHAM AND B. F. DODGE. *Plating*, **36**, 251 (1949).

This is a brief survey of recent legislation and the problems facing the electroplating industry, followed by illustrations and comments on a number of operating waste treatment plants in this country.

H. P. ORLAND

Preliminary Planning for Plating Room Waste Disposal. BY C. F. GURNHAM, B. F. DODGE, AND D. C. REAMS. *Plating*, **36**, 1136 (1949).

This is a general summary of the type of information needed in planning for future regulation of plating room wastewater disposal in plants that have so far escaped the attention of pollution control authorities. Among the data required for concentrated wastes are listed type of bath, date and time of dumping, volume dumped, time required to empty tank, analysis at time of dumping, treatment given at time of dumping, and place where dumped. Similar records are advised for dilute wastes and plating baths, as well as the analyses and average life of the latter solutions.

Particularly pertinent in an appraisal of the data is a record of any treatment used in the past and subsequently abandoned, with complete notation as to reasons for discontinuing the process of great importance are complete records of chemical usage during the survey period, including anodes dissolved; electrical power consumed; and the daily output of plated work. The longer the survey period can be made, the more useful will be the data obtained. Attention is called to the possibility of production savings accruing as an additional benefit from a survey of the type outlined.

H. P. ORLAND

Viscosity of Pulping Waste Liquors. BY KENNETH A. KOBE AND EDWARD J. MCCORMACK. *Ind. and Eng. Chem.*, **41**, 12, 2847 (Dec., 1949).

The viscosities of sulfite waste liquor, sulfate black liquor, and soda black liquor were determined at various temperatures. Density and total solids determinations were also made. The resulting data were analyzed and a chart and nomogram are presented indicating the viscosity-temperature relationship for various solids percentages. The chart and nomogram apply to all three of the waste liquors with an accuracy of 5 per cent.

At 30 per cent solids the viscosity rises rapidly. This suggests that any considerable handling of waste liquors should be done while their solids concentrations are somewhat below 30 per cent.

Examples of data presented are as follows: Waste sulfite liquor with a 15 per cent solids content had a density of 1.072 gm. per cc. and a viscosity of 2.054 centipoise at 19.9° C. Similar data for sulfate black liquor are 14.3 per cent solids, 1.085 gm. per cc., 1.960 centipoise at 203° C.; for soda black liquor having 15.1 per cent solids, 1.082 gm. per cc., 1.896 centipoise at 22.0° C.

The data presented cover a range of solids about 10 to 50 per cent and a temperature range of about 0° to 97° C. The viscosity of the three liquors varies from approximately 0.5 to 20 centipoise.

PAUL D. HANEY

Book Reviews

The Examination of Waters and Water Supplies. By Edwin W. Taylor. The Blakiston Co., Philadelphia, Pa. Sixth Edition, 1949. $12.00. 819 pp.

This book dealing with both analysis and purification of waters for public supply has been a world famous reference for over 40 years. All material has been brought up-to-date, particularly with respect to references to recent scientific literature. This sixth edition retains the traditional format.

The contents have been carefully revised throughout, the chapters on the collecting areas, underground supplies, waterborne disease, bacteriology of water samples, and disinfection of water supplies having been extended and rewritten.

Numerous tables and plates, as well as a 41-page appendix, increase the usefulness and practicality of this 819-page volume. Although primarily British in approach and illustration, frequent reference to American and other practice makes the coverage general enough to make the book a standard reference work.

Of particular interest to sewage works personnel is the entire Part VI of the book (9 chapters, 133 pages), dealing with bacteriological examination of water, sewage, and effluents.

H. P. Orland

Patent Practice and Management. By Robert Calvert. Searsdale Press, Searsdale, N. Y. 1950. $5.00. 371 pp.

This new kind of book combines the author's experience of 10 years as a research laboratory director with 15 years in subsequent patent practice. Weaving the elements of patent law with the threads of business judgment into a new pattern of great interest and practical value, it deals particularly with the patent problems of the inventor and executive and presents the whole subject from their viewpoint and in their language.

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5. Patent licenses, desirable and undesirable provisions, and complete license form.
6. Use and misuse of patents.
7. Claim interpretation and validity and trend of recent court decisions.
8. Infringement, extent of liability, and test for infringement and equivalents.
9. Writing of specifications and claims, with an outline and a complete application written from the outline.
10. Patent policies of institutions, medical, educational, and government.
11. Tax law of research and invention.

H. P. Orland

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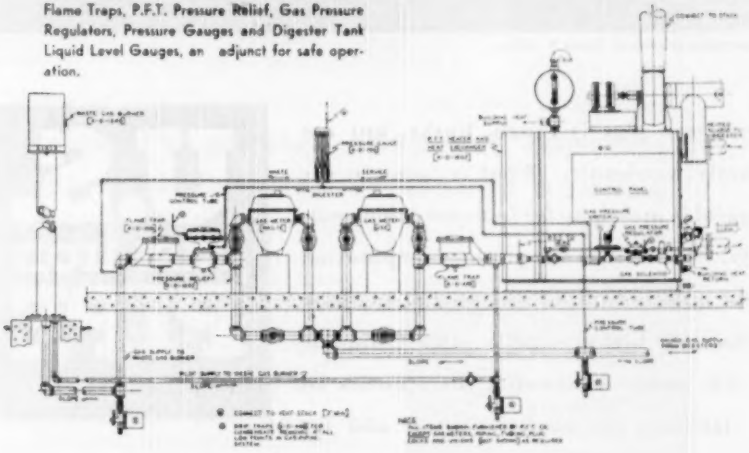

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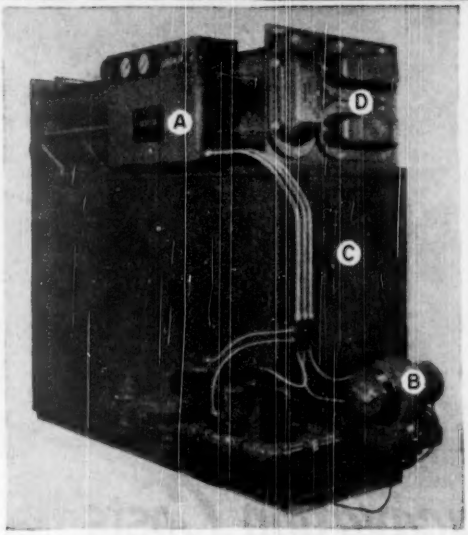

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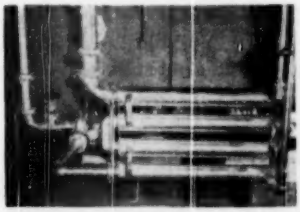

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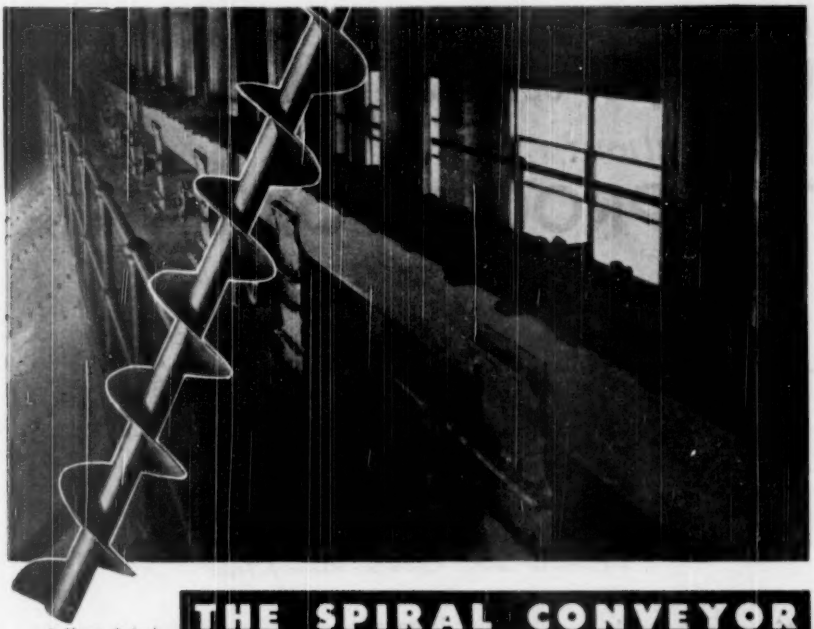

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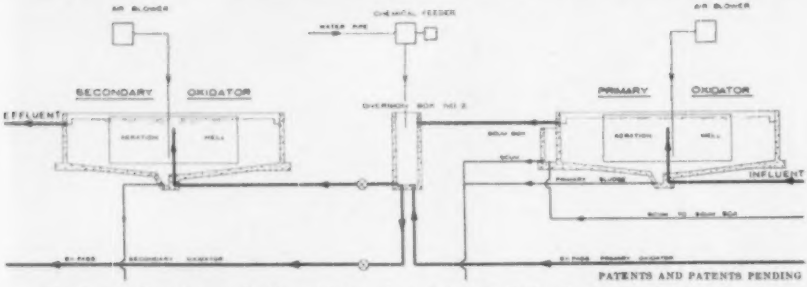

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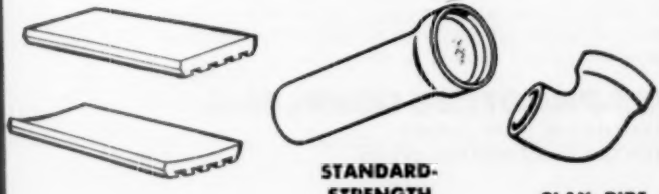

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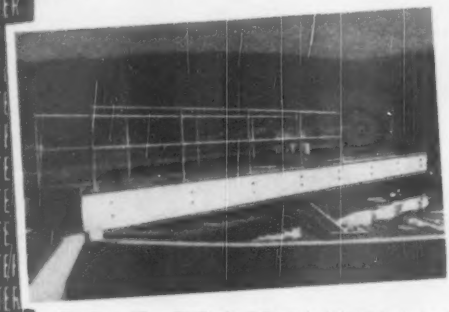

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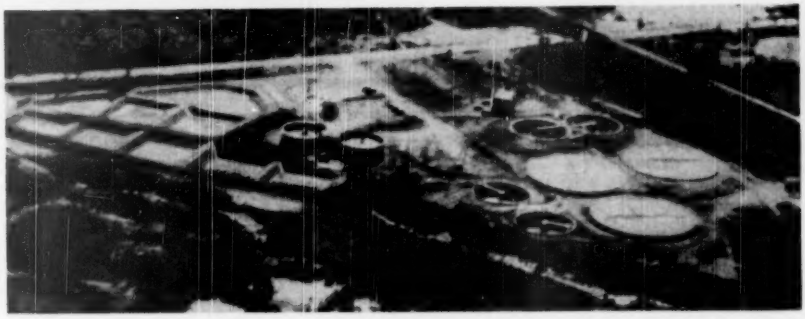

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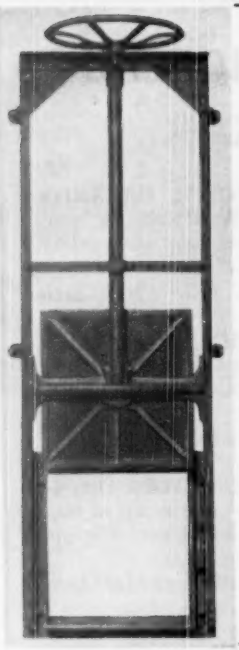

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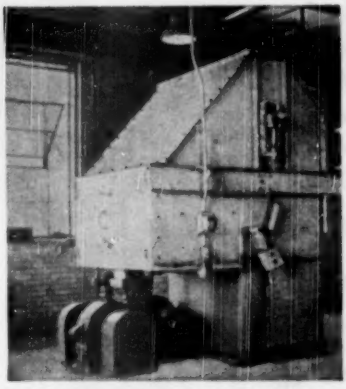

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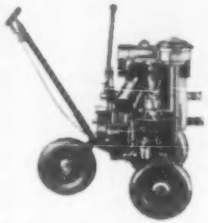

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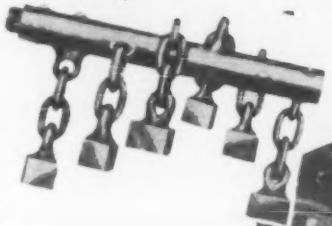

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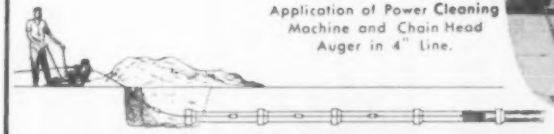

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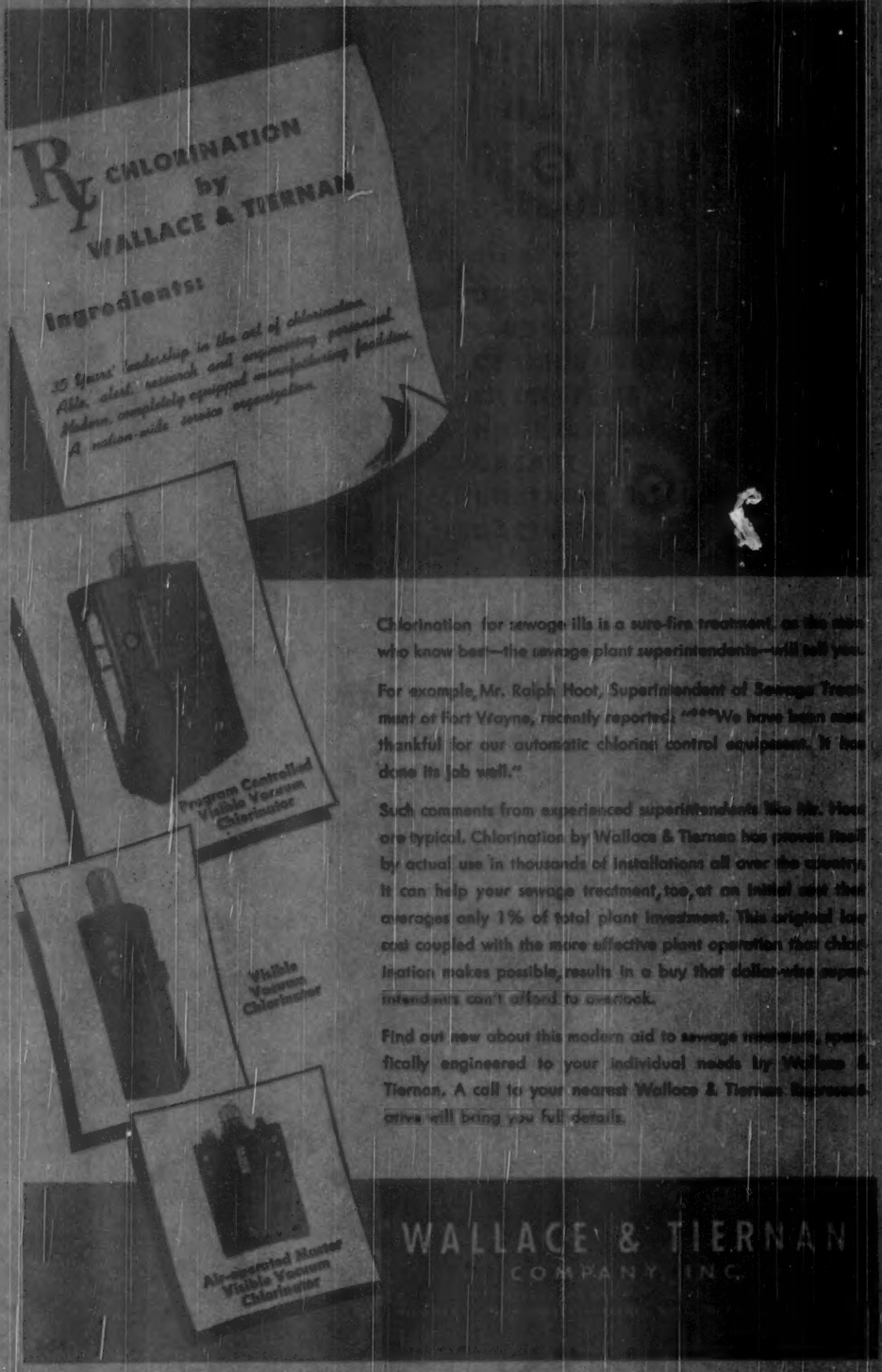

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